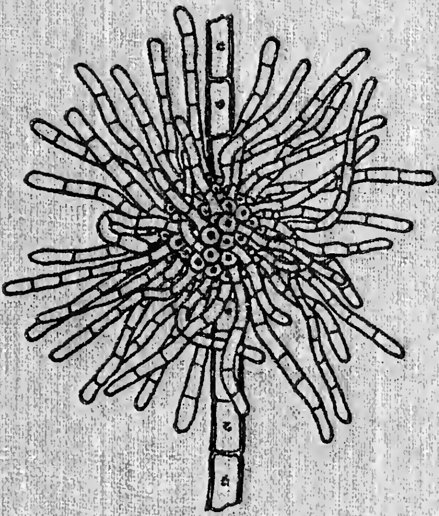

CONTRIBUTIONS

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No. 52.

THE SENSORY POTENTIALITIES OF THE NUDIBRANCH 'RHINOPHORE.'

By Leslie B. Arey.

No. 53.

STUDIES ON AMPHIOXUS.

By E. L. Mark and W. J. Crozier.

I. THE PHOTORECEPTORS OF AMPHIOXUS.

By W. J. Crozier.

From The Anatomical Record, Vol. XI, No. 6.

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46. The sensory potentialities of the nudibranch 'rhinophore.'[1] Leslie B. Arey, Northwestern University Medical School.

Nudibranch mollusca possess a pair of short, robust dorsal tentacles which are commonly perfoliate or ringed and which may or may not be retractile. These important looking tentacles have long been designated 'rhinophores,' and it is tacitly assumed that they are indeed specialized olfactory organs. The presence in certain species of long, more or less dorsally placed tentacles, in addition to the oral tentacles and rhinophores, heightens the suspicion that the latter may perhaps serve some particular sensory function.

The sole experimental evidence upon which the assignment to the rhinophores of an olfactory activity rests seems to be found in the observations of Graber in 1877 (Biol. Centralbl., Bd. 8, No. 24, pp. 743–754). Graber brought oil of rose near the head of Chromodoris elegans and observed the withdrawal of the rhinophores to be quicker and more vigorous than that of the oral tentacles. He emphatically states, however, that the post-branchial region is the most sensitive part of the body.

It would thus appear that the convenient term 'rhinophore' is of dubious propriety. For this reason Bermudian nudibranchs were subjected to experimentation designed to test their sensory potentialities. Unless otherwise stated the following account applies to Chromodoris zebra Heilprin.

Tactile stimulation. When a rhinophore is touched lightly with a glass rod it is jerked back precipitately within its protecting collar. The sensitivity of the rhinophore to gentle stimulation is astonishing and the explosive type of response is, within wide limits, independent of the strength of the stimulus. Fatigue comes on but slowly, responses of somewhat diminished intensity being readily obtained after fifty successive stimulations at ten-second intervals.

The oral tentacles, gill plumes and the general body-surface all respond to tactile stimulation. It is unsatisfactory to list the several regions of the body in the order of their sensitivity, for the types of responses are not all comparable. It appears, however, that the so-called rhinophore is the most sensitive part of the body and considerably more so than the oral tentacles.

Thermal stimulation. The head region and especially the oral tentacles react distinctly to water at 40°–50°C. applied with a pipet. The rhinophores, on the contrary, give faint and rather doubtful responses except to temperatures as high as 50°C.

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[1] Contributions from the Bermuda Biological Station for Research, No. 52.

Chemical stimulation. Equal volumes of various chemical solutions were applied from a constant distance with a pipet. Solutions of 1 M of maltose, or sucrose, or M/2 of lactose were without effect upon all parts of the body, although 3 M glycerine did evoke general responses. Several alkaloids had very weak effects or none at all. Alcohols and organic acids in concentrations of M/10 called forth strong general responses. The chlorides of the alkali metals Na, K, NH_4 and Li likewise stimulated the body in general, the rhinophores and oral tentacles, however, showing the greatest sensitivity. Solutions of substances which produce in man the taste sensations recognized as acid, bitter, salty and alkaline were applied in various concentrations. The gills fail usually before other parts, although all responses gradually weaken with increasing dilution.

From the foregoing tests it becomes evident that the rhinophore is not only extremely sensitive to chemical stimulation of diverse sorts, but that this sensitivity is only second to, if indeed it does not equal, that of the oral tentacles, which from their position might be suspected *a priori* of a specialized gustatory or common chemical function.

Olfactory stimulation. Saturated solutions in sea water of numerous essential oils and decoctions of decaying marine invertebrates were prepared and applied by the pipet method. The rhinophores react strongly to these solutions, but other parts of the body appear to be, so far as one can judge from the dissimilarity of the responses, equally sensitive. When a drop of oil is held for some time midway between the rhinophores no response ensues. If the rhinophore, or body, be touched gently with a drop of pure oil, the reaction is weaker than to a saturated solution. Here the number of sense organs stimulated is undoubtedly a complicating factor, yet there is suggested further that the response is one to an olfactory, rather than to an irritative or 'smarting' stimulus.

An essentially similar behavior to odorous substances was found in Chromadoris roseapicta, Elysia crispa and Fiona marina. Besides the rhinophores, Facelina goslingi possesses long, more or less dorsal tentacles, and short oral ones. The longer pair reacts more vigorously to solutions of the oils than do the rhinophores.

Summary. The entire body of Chromodoris zebra is sensitive to mechanical, common chemical, gustatory and olfactory stimuli. The head region is somewhat responsive to the application of increased temperature. Several other nudibranchs exhibit general olfactory sensitivity. Of the various parts of the body, the rhinophore is most sensitive to touch; is second, if not equal to the oral tentacle, in its response to chemical stimulation; and shares its sensitivity to odorous substances with the oral tentacle. In at least one species, Facelina, the long posterior tentacles react more vigorously to solutions of essential oils than do the rhinophores. Only to thermal stimulation is the rhinophore (of Chromodoris) clearly inferior in sensitivity. Hence the so-called rhinophore, like the insect antenna, is a compound sense organ, for which the misleading term 'rhinophore' is highly inapt.

STUDIES ON AMPHIOXUS

By E. L. Mark and W. J. Crozier

51. I. *The photoreceptors of amphioxus.*[2] W. J. Crozier, Bermuda Biological Station.

An incandescent filament appropriately mounted was substituted for the ocular on one limb of a binocular microscope; by means of this device it was possible to secure, with properly adjusted diaphragms, an intense beam of light, microscopic in diameter, which was focussed within or upon various portions of Branchiostoma carribaeum. The exact location of the light-spot, and the extent of light scattering by the tissues, were observed through the other tube of the binocular. Practically every portion of the body of a number of lancelets was examined in this way in a dark-room; precautions were taken to avoid mechanical stimulation, to which amphioxus is very sensitive in the dark. No responses were obtained except when the light was focussed upon or within the ventral half of the nerve cord. It was possible to prove, notably by experiments with individuals in which portions of the integument were thoroughly anaesthetised, that this stimulation did not concern photoreceptors in the skin.

The integument of amphioxus therefore contains no normal photoreceptors. As indicated by Parker's less precise tests, the optic cups within the nerve-tube are probably the light-sensitive organs in this animal. This conclusion is substantiated by the details of the illumination trials, and particularly by the demonstration of photomechanical changes in the pigment cups of the "Sehzellen." Some evidence was secured which points to the photosensitivity of the "dorsal Sehzellen" of Joseph. The region of the anterior pigment spot is insensitive to light.

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[2] Contribution from the Bermuda Biological Station for Research, No. 53.

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THE MOVEMENTS OF THE TENTACLES IN ACTINIANS.

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PEDAL LOCOMOTION IN ACTINIANS.

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THE MOVEMENTS OF THE TENTACLES IN ACTINIANS[1]

G. H. PARKER

ONE FIGURE

The tentacles of actinians have long been declared to be capable of carrying out many of their normal activities even after they have been cut from the body of the polyp to which they belong. This peculiarity, which was recorded apparently first by von Heider ('79, p. 248) and has since been noted by others (Parker, '96; Wolff, '04; Chester, '12), has been accepted as evidence that each tentacle contained a neuromuscular mechanism sufficient for its own activity and that it is therefore not dependent upon the nervous control of other parts of the animal's body for the production of those movements that it ordinarily exhibits. To test the validity of this view, which has recently been questioned by Rand ('15, p. 208), was the object of the studies recorded on the following pages.

The work was carried out on Metridium marginatum Milne-Edwards, and Sagartia luciae Verrill at Woods Hole, Massachusetts, and on Condylactis passiflora Duch. and Mich. at Bermuda. The advantage of Condylactis for this kind of work is evident because of the large size of its tentacles, and almost all of the experiments recorded on the following pages were performed on this species.

In a full-grown Condylactis the oral disc may measure as much as 12 cm. in diameter and carry as many as a hundred tentacles. About half of these are near the outer edge of the disc and the remainder are scattered toward the mouth. The mouth is central in position, usually diglyphic, and partly covered by folds of the peristome.

Each tentacle is from 12 to 15 cm. long, with a diameter of about 1.5 cm. at its base and terminates distally in a blunt end in which there is a pore. The tentacles are light brown in color

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[1] Contributions from the Bermuda Biological Station for Research. No. 54.

with whitish markings; in some specimens they are tipped with pink. They are at most sparsely ciliated and provided with only a few nematocysts; their walls are thin. When cut they may contract from a length of 15 cm. to 1.5 cm.

If an expanded quiescent tentacle is touched near the tip with a silver sound or a glass rod, the tentacle contracts, usually bending toward the stimulated side. The tentacle often sticks to the object with which it is touched and it may in contracting thus exert a considerable pull, showing that its surface is remarkably adhesive and that its musculature is vigorous. This adhesiveness is especially noteworthy in specimens with pink-tipped tentacles and these individuals are known to adhere with the pedal disc to the glass wall of an aquarium more tenaciously than those without such coloration.

If a strong stimulus is carefully given to a tentacle not closely surrounded by others, the tentacle may contract without touching the others and yet these may also respond, thus giving evidence of basal transmission from tentacle to tentacle. A tentacle, if only once slightly touched, usually quickly returns to its former position and quiescence.

If a piece of crab-meat or fish-flesh is brought in contact with a tentacle, it adheres firmly to the tentacle which quickly contracts and is usually covered by several adjacent tentacles. The piece of flesh is thus held on the disc while the mouth gradually moves toward it and on reaching it swallows it. The animal then slowly returns to a state of quiescent expansion.

If a tentacle is cut off at almost any level, the stump at first contracts but after a time again elongates to its appropriate length, its cut end being closed by a nipple-shaped pucker (Rand, '09, '15). The portion of the tentacle cut off, also contracts and will remain indefinitely so at about one-third its original length. Such a fragment of tentacle will live in sea-water for several days.

In specimens of Condylactis under natural conditions tentacles are often seen marked with regions of pronounced constriction. The portion of the tentacle distal to the constriction has been often observed to be cast off and it is probable that these constrictions are the first step in a process of tentacular autotomy that seems to be characteristic of Condylactis.

In an experimental study of the tentacles, it is necessry among other things to cut off the tentacles from the body of the polyp and to study them thus isolated. When a tentacle is treated in this manner, it contracts, as already stated, to about one-third its former length and it will remain in this condition alive in sea-water many days. At the moment the çonnection of the tentacle with the actinian's body is severed its fluid content in part escapes and water flows out of the polyp from the hole left on the stump, thus showing that the tentacle as well as the animal is distended under slight pressure. It might, therefore be assumed that the full expansion of the tentacle was due to this slight pressure and that, when the tentacle was cut off, the partial contraction that followed was due to the release of the tentacle from internal pressure.

To test this hypothesis a tentacle, after having been cut off from the polyp and allowed to come to as full distension as it would, was tied to the end of a glass tube preparatory to distending it further with sea water. On binding it to the tube it contracted vigorously to only a small fraction of its former length and remained thus for hours. Sea-water was finally run into it through the attached tube and when this water stood at a height of 8 to 10 cm. in the tube, the tentacle without expanding began to allow the contained fluid to escape through its terminal pore. This was then tied off and the pressure in the tentacle was increased by running more water into the tube. At about 14 to 15 cm. of pressure the tentacle without having expanded ruptured on the side and with the escape of the water it contracted completely. During all of this experiment the tentacle was rigid and tight and very unlike the normal tentacle, which when touched gently or moved by water currents is evidently under internal pressure but pressure of only a very slight amount, probably not more than that of a few millimeters of water. It is clear from these observations that the pressure of sea-water as applied in this experiment is not a means of restoring a severed tentacle to a normal state and that the further contraction that often appears in a partly contracted tentacle as the internal pressure increases shows that the applied pressure itself is a stimulus to contraction (Rand, '09, p. 206).

If then, the contraction of a severed tentacle is not due, simply to a release from pressure, it may depend upon some influence emanating from the stump of the tentacle or from the polyp as a whole, which influence on being interrupted by the cut allows the tonus of the tentacular muscles to exert itself unrestrainedly. To test this hypothesis, tentacles were partly cut through about midway their length and then allowed to come to a condition of quiescence. Such tentacles became normally expanded and elongated proximal to the cut but were somewhat contracted distal to it, the cut itself exhibiting a well marked lateral pucker. Such tentacles, if stimulated vigorously at the base, would exhibit longitudinal contractions not only in the basal portions but also to some extent in the portions distal to the wound. It thus appears that the contraction of the distal part of a tentacle is not overcome even through the connection of this part with the proximal part by a bridge of tissue capable of transmitting impulses from the polyp or basal part of the tentacle to the peripheral part of this organ.

If the contraction of the severed tentacle is not due to loss of pressure, or loss of a proximally located influence inhibiting tentacular tonus, it is most probably due to the influence of the cut itself. It is well known that wherever an actinian is injured the muscular tonus of the given region is greatly increased and it is therefore not surprising that on cutting off a tentacle the whole organ should contract in a more or less permanent way. That this is the probable explanation of the partial contraction of a severed tentacle is seen from the fact that if such a tentacle is firmly tied at its base, whereby its injury is considerbly increased, it becomes permanently still more contracted in that the tonus of its neuromuscular mechanism is appreciably increased.

On the assumption that the partial contraction of the severed tentacle had an operative source, I tried to avoid this difficulty by anesthetizing the base of a tentacle so as to obtain a non-responsive part to cut and tie and leave the greater part still responsive. But I failed in devising any technique by which the root of the tentacle could be rendered insensitive and the distal part left unaffected.

I therefore turned to methods of procedure that were least disturbing to the normal tentacles. The best of these consisted in holding at the surface of the sea-water a quiescent severed tentacle by means of a minute hook made by bending slightly the pointed end of an entomological pin (fig. 1). Into the open end of such a suspended tentacle sea-water could be run from a glass pipette and thus the tentacle could be brought to a reasonable degree of distension. Such severed tentacles when first put on the hook were contracted to about one-third their normal length. As their condition did not differ essentially from that of loosely floating severed tentacles, I concluded that the effect of the hook was negligible. On discharging water into them they gradually expanded till they were about two-thirds as long as they were before their separation from the polyp. They exhibited moreover just about that degree of distension and mobility that was seen in the attached tentacles. If, now, more water was discharged into them, they were very likely to elongate a little and then contract considerably discharging much of the contained water. This response confirms the opinion already

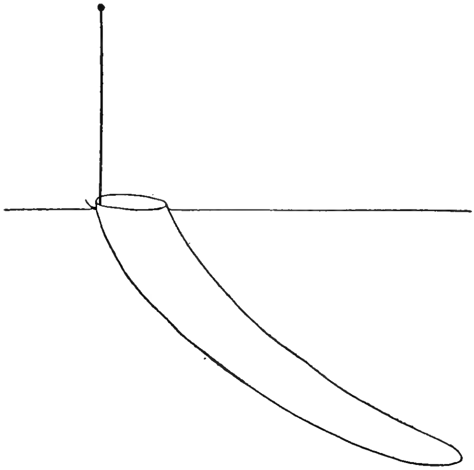

Fig. 1

expressed in this paper that an increase of internal pressure beyond a certain point will call forth a vigorous muscular contraction. If, however, this mild pressure is not exceeded, a tentacle expanded to about two-thirds its natural length and exhibition its normal pliability is readily obtained.

The response of the tentacles to internal pressure is probably not without its significance in the general reactions of actinians. When a sea-anemone contracts vigorously, its fluid contents are put under much increase of pressure and this increase must be almost instantly transmitted to the contents of each tentacle, thus stimulating it to contraction. In this way the whole circle of tentacles might easily be brought to general withdrawal through the individual response of the neuromuscular mechanism of each tentacle acted upon by a common purely physical factor. The ease with which such a controlling factor could be confused with nervous influence must be apparent.

Having obtained in isolated tentacles a close approximation to the resting condition of the attached tentacles, it remained to compare the reactions of these two classes. Suspended tentacles filled to about two-thirds their natural length will remain quiescent in sea-water for a considerable period. From time to time, however, they show spontaneous movements consisting of slight contractions and twistings by which more or less of their contained fluid will be discharged. If this is replaced they will reëxpand and thus periods of quiescence are followed by periods of spontaneous movements. In these respects the severed tentacles reproduce very closely the behavior of the normally attached tentacles.

If a suspended tentacle is gently touched it exhibits irregular reaching and writhing movements, whereby it will partly empty itself. After it has been refilled, a more vigorous stimulus will induce a more or less spiral contraction, in which state the tentacle will remain some minutes. Again it must be refilled. In the response both to the slight and to the vigorous mechanical stimulus the severed tentacle reproduces in a most striking way the movements of the attached tentacles under like stimulation.

When an attached tentacle is gently touched on one side midway its length, the tentacle as a whole contracts but without much bending. If it is touched on the tip, the response is mostly a terminal waving back and forth. If it is stimulated on one side near the base, the contraction is chiefly basal and on the stimulated side. These responses are reproduced quite clearly by isolated tentacles. Thus the responses of the two classes of tentacles to localized stimuli are strikingly similar.

If a small amount of one per cent acetic acid is discharged on an expanded severed tentacle, the tentacle contracts quickly with a curious appearance as though it were withering. After it has been washed with seawater, it will expand again in about three to four minutes. A second and a third response have been elicited from such tentacles and these responses reproduce most strikingly the movements of attached tentacles. To a tenth per cent acetic acid both classes of tentacles showed a slight local shortening. To a hundredth per cent they responded by a slight curving. To a thousandth per cent neither kind of tentacle showed any response whatever as was also the case when pure seawater was discharged on them from a pipette.

In none of my experiments on Condylactis did I get evidence of a specific contraction of the circular muscle fibers to stimulation by very weak acetic acid as von Uexküll ('09) found for Anemonia.

To rain water discharged on the tentacles from a small pipette, no noticeable response was made by either class, but to seawater containing the juice from a crushed mussel the attached tentacle exhibited active writhings often accompanied by elongation. It was remarkable how strikingly similar to these were the responses of the isolated tentacles to the same juice.

To a one per cent solution of quinine hydrochloride in rain water both classes of tentacles responded by quick contractions and often local constrictions. The solution was applied by a pipette to limited areas on the outside of the tentacles.

In all the tentacular reactions studied the responses of the isolated tentacles agreed most strikingly with those of the normally attached tentacles. Of course the reactions of the isolated tentacles are not exact duplicates of those of the attached ones. They are feebler and less precise, but aside from these peculiarities they are so strikingly similar that their resemblance is the conspicuous feature of the operation. The differences between the two sets of reactions are due in my opinion to the partial contraction of the excised tentacles. This partial contraction, as already pointed out, seems to be purely operative in its source, and it is this, in my opinion, that is the cause of the lowered responsiveness rather than the absence of some extra-tentacular influence. That this explanation is correct, may be shown by stimulating unsevered tentacles that are already in a state of partial contraction due to a preceding stimulation. When such a tentacle is restimulated, it responds, as repeated trials have shown me, with just that partial vigor and lack of precision which characterize the isolated tentacles. I, therefore, believe that we have ample grounds for concluding that the slight differences in the reactions of isolated and attached tentacles are purely operative.

The tentacles of Condylactis, like those of most actinians, possess a longitudinal musculature in the ectoderm and a circular one in the entoderm and are supposed to exhibit a nervous layer with each muscular layer. The means of stimulation thus far used in these experiments have been applied to the ectoderm and the responses thus called forth have been chiefly in the longitudinal muscle of this layer, though the deeper circular muscle has undoubtedly also been generally involved. With tentacles of the size of those in Condylactis it is possible to apply stimuli to the entodermic surface as well as to the ectoderm and by this procedure some idea of the responsiveness of this surface can be obtained.

Into an isolated tentacle suspended in seawater by a hook and so held that its open end was well above the surface of the water, a small amount of one per cent acetic acid was injected. After about two seconds the tentacle gradually shortened. It was then thoroughly washed with seawater and rehung. When it had become reëxpanded, the discharge of a small amount of one per cent acetic acid on the ectodermic surface was followed by an immediate shortening. These tests were repeated several times and always with the same outcome; a shortening after two or three seconds when the stimulus was applied to the interior of the tentacle and a sudden shortening when it was applied to the exterior. When mussel juice was substituted for acetic acid, a writhing response was produced in about four seconds by the application of this stimulus to the inside of the tentacles, but this response took place almost immediately when the juice was applied externally. Quinine hydrochloride in one per cent solution was immediately effective when applied to the exterior and called forth a response only after more than a minute, when applied internally.

It thus appears that stimuli which call forth specific reaction when applied to the ectoderm of the tentacles induce the same movements when they are applied to the entoderm, but only after a somewhat longer interval.

Is this difference in the rate of response a difference in the nervous activities of the ectoderm and the entoderm of the tentacle or is it to be accounted for by the direct stimulation of the ectoderm in the quick form of response and the less direct one in the slow form in that in the latter it requires an appreciable time for the stimulating fluids to pass from the cavity of the tentacle through its wall to the ectoderm? If the latter explanation is correct, it ought to be possible to get evidence of the penetration of the wall of the tentacle by such a solution as that of acetic acid.

To test this question an isolated tentacle was suspended in seawater and close to it was hung a piece of blue litmus paper; near at hand in the seawater was also suspended a piece of red litmus paper. Deep into the seawater filling the tentacle was now discharged about a drop of one per cent acetic acid. The tentacle contracted slightly but not enough to cause it to overflow. In about half a minute the blue piece of litmus paper began to redden, showing that the acid had transfused the living walls of the tentacle. Meanwhile the piece of red litmus paper had begun gradually to change blue, doubtless from the slight alkalinity of the seawater. In two other tests evidence of the penetration of the wall by acid was obtained in 45 seconds and in 55 seconds.

To be certain that the reddening of the litmus paper was not due to any leakage through the pores at the end of the tentacle, the experiment was repeated with a tentacle the tip of which was tied. This brought about an extreme contraction of the tentacle. Nevertheless the transfusion of acid through the wall of the tentacle was observed in from two to two and a half minutes. The longer period needed for the transfusion in this instance, as compared with that in tentacles not tied at the tip, is doubtless due to the increased thickness of the wall of the tentacle in contraction. It therefore seems not improbable that the response of a tentacle to chemical stimuli discharged into its interior is not due to the stimulation of entodermic receptors but to the transfusion of the substances through the wall of the tentacle to the ectoderm, where a normal external stimulation probably takes place.

Another method of testing for an entodermic nervous system is as follows. It has already been stated that a suspended isolated tentacle will contract when a one per cent solution of quinine hydrochloride is discharged on it or into it; quickly in the former case, more slowly in the latter. If such a tentacle is bathed externally in a preliminary way with a half per cent solution of cocaine hydrochloride, after five to eight minutes it will no longer respond to the quinine solution. If now this solution is at once discharged into the interior of the tentacle there is likewise no response. Thus the tentacular entoderm does not appear to be a receptive surface for internal stimuli, but merely transmits in a physical way substances which become effective stimuli only after they reach the ectoderm. The view that the tentacular entoderm is not a receptive surface and may contain no nervous tissue whatever, is supported by the fact that the muscles responding to all the stimuli applied to the interior of the tentacle are the distantly located longitudinal muscles, not the near-by circular muscle.

These various lines of evidence naturally raise the question whether there is after all in the entoderm of the actinian tentacle any nervous system whatever. It has been pointed out elsewhere (Parker and Titus, '16) that the histological evidence for this layer is by no means conclusive and the physiological evidence as thus far elicted from Condylactis is entirely opposed to a belief in its presence. In only one point do I find anything in the physiology of the tentacular entoderm that is suggestive of a contained nervous system. It has already been observed by Rand ('09, '15) that when a tentacle of Condylactis is cut off, the stump closes through the action of the circular muscles, whereby a nipple is formed. This closure does not occur in tentacles anesthetized by chloretone. I have elsewhere shown that chloretone will not check the action of the muscles in the acontia, though it is very effective as a narcotizer for the neuromuscular mechanism proper. I therefore believe that in actinians it directly effects nervous action and that its influence on muscle alone must be of an indirect kind. The narcotization of a tentacle must abolish this indirect influence, though I cannot say whether or not this involves some slight nervous activity. Aside from this I have been unable to get any evidence that the entoderm of the tentacle of Condylactis contains nervous elements. If such elements are present, they must be of a very primitive kind and certainly much less effective than those in the ectoderm, for the circular muscle fibers never react quickly and seldom respond as a whole in the way that the longitudinal muscle does, but much more usually in a local fashion, whereby rings of constriction are formed as in tentacular autotomy and other such spincter-like activities.

A good example of the different action of these two muscles is seen in the following experiment. If a suspended tentacle filled in the usual way with seawater is vigorously stimulated mechanically at one point, the whole tentacle instantly contracts. On being refilled it reëxpands in a few minutes except for a marked circular constriction in the region stimulated; this then gradually disappears. Thus the quick action of the longitudinal muscle and the slow action of the circular muscle is well demonstrated. If, now, the experiment is repeated but with the point to be stimulated first thoroughly narcotized by dropping upon it crystals of magnesium sulphate, the stimulus is followed by a pronounced ring-like constriction in the circular fibers but by hardly any contraction in the longitudinal muscles. For these reasons I regard the ectodermic musculature as under the control of nervous elements and the entodermic at least open to direct stimulation.

Another general feature of the tentacles is the polarity exhibited by these organs. Thus the tentacular cilia regularly beat from the base toward the tip of this organ and hence exhibit polarization, but this feature is better seen in the neuromuscular reaction of these parts. When the tip of a tentacle is vigorously stimulated the whole tentacle is likely to respond, but when a point lower down on the side of the tentacle is stimulated, the reaction is chiefly from this point proximally. In other words transmission is more readily accomplished from the tip toward the base of the tentacle than in the reverse direction. The same kind of evidence comes from the reparative steps in regeneration. If a tentacle is cut off, the stump contracts vigorously and on reëxpanding forms a terminal nipple; the cut face of the distal segment usually contracts only a little and seldom if ever closes the open wound. Yet, if such a distal piece is again cut crosswise, its proximal part contracts and eventually forms a nipple while the distal piece remains almost unaffected. The polarization thus exhibited is in the same direction as that which was shown by the reactions of the attached tentacle to mechanical stimulation.

If the tentacles of an animal which has been thoroughly anesthetized with chloretone are touched, no response whatever follows. If they are cut neither the proximal nor the distal parts contract but both remain flabbily open. In consequence of these conditions I believe that the polarity of the tentacle in so far as it is exhibited by the reaction just noted is of a nervous nature, for it disappears on applying a drug which eliminates nervous activity.

When the nervous structure in the tentacle of actinians is examined with the view of seeking some condition upon which this form of polarity can be based, a most simple relation is discoverable. As Grošelj ('09, p. 290) has pointed out, the nerve fibrils that arise from the sense cells in the tentacles of actinians extend as a rule in a direction corresponding with the length of the tentacle. In Bunodes many of these cells are bipolar and in that case one fibril extends distally along the tentacle and the other proximally, but there are also in this actinian a goodly number of cells that are unipolar and in such instances the fibrils almost invariably extend toward the base of the tentacle. In Cerianthus almost all the sense cells in the tentacular ectoderm are unipolar and their fibrils run almost without exception toward the base of the tentacle. As these fibrils transmit impulses away from the cell bodies with which they are associated, it follows that in both these actinians transmission must be predominantly toward the base of the tentacle and that consequently the region of response would be largely proximal to the region of stimulation. This is what is to be seen in the neuromuscular reactions of most actinian tentacles and I, therefore, believe that the polarity of these organs, as evidenced in the processes just mentioned, is dependent upon the proximal direction taken by the sensory fibrils in these structures whereby the nervous impulses are led to flow predominantly toward the base of the tentacle (Rand, '09, p. 235). This anatomical interpretation of the polarity of the tentacle is supported by the observation made by Chester ('12, p. 468) that after two tentacles of Metridium have been grafted together base to base there is no change in their (ciliary or) muscular polarity.

Concerning the relation of the tentacle to the organization of the animal as a whole, the preceding discussion must make several points clear. In Condylactis the tentacle is filled with fluid, whose slight pressure is dependent upon the activity of the body as a whole. It also receives from other parts of the animal through its base nervous impulses by which its neuromuscular mechanism may be set in operation, though this process is much more generally accomplished by the direct stimulation of the tentacle itself. Aside from the supply of nutriment transmitted to the tentacle from the general store produced in the gastrovascular cavity of the animal (Jordan, '07), the transmitted pressure and the moderate inflow of nervous impulses are the only significant contributions of the whole animal to the tentacle. Yet, as the experiments already described show, neither of these are really essential to the responses of the tentacle, whose activities can be carried out by its own neuromuscular mechanism. How striking this condition is, can be made plain if the coördinated efficiency of an actinian's tentacle after separation from the body is compared with the state of an amputated appendage from an arthropod or a vertebrate. In the latter practically all traces of spontaneous movement and coördination have disappeared and only spasmodic jerks can be called forth by vigorous stimulation. Whereas in the former the range of response and the coördination of the individual acts differ from those of a normal animal, as has already been shown, only through slight operative disturbances. In seeking among the organs of the higher forms for a parallel to the actinian tentacle, one is continually reminded of the vertebrate heart, whose essential activity is so slightly interfered with even by removal from the body. The similarity in the action of the heart and of the tentacle under these circumstances is due to the fact that each possesses within its own substance a neuromuscular mechanism essentially independent of the rest of the body. The same is true of the separate arms of certain starfishes, which may move about as independent organisms before they have regenerated their deficiencies. Nor is the tentacle of the sea-anemone the only organ in this animal that exhibits organic independence of the kind already described. As will be shown in a subsequent paper, the pedal disc of the actinian when separated from the oral disc may creep about for a long time with well coördinated locomotor waves. This example, as well as others that might be cited from the actinians, as for instance the acontia, show the great independence of the parts of these animals in contrast with those in most other forms. To be sure, an actinian tentacle has never been known to regenerate a new individual and in this respect the tentacle is a totally subordinate organ, but in the direction already indicated it exhibits most remarkable independence and though this question is obviously a relative one, when the activities of an isolated actinian tentacle are compared with those of the separate appendage of a higher animal there seems to me not the least ground for the opposition raised to the view of the high degree of organic independence of the tentacles from the rest of the body of actinians.

SUMMARY

1. The severed tentacles of Condylactis may be suspended in seawater with least disturbance to themselves by means of a small metal hook.

2. Under such circumstances they can be inflated by running water into them till they have attained about two-thirds their natural length. In this condition they are under a fluid pressure very nearly that which was natural to them and not greater than a few millimeters of water.

3. If this internal pressure is increased much beyond that at which the tentacle expands to about two-thirds its former length, the tentacle will contract vigorously and discharge much of the contained seawater.

4. The slightly contracted state of the expanded, excised tentacle is not due to lack of pressure, nor to the absence of inhibitory influences from the rest of the polyp, but to the cut at its base, which increases the tonicity of its neuromuscular mechanism.

5. Excised tentacles when stimulated by mechanical means, by food, or by chemicals react in essentially the same way as attached tentacles do. Excised tentacles are feebler and less precise in their reactions than attached tentacles are, a difference due to their partly contracted state, which in turn is dependent upon operative complications.

6. Stimuli when applied to the ectoderm of a tentacle are followed quickly by a muscular response; when applied to the entoderm they are followed slowly by the same form of response. This difference is due to the fact that the entodermal surface is not receptive and that stimulating substances applied to that

surface make their way only slowly through the wall to the receptive ectoderm, an operation which can be demonstrated in the case of acetic acid.

7. If there is a nervous layer in the entoderm of the tentacles of Condylactis, it must be extremely simple in structure and function as compared with that in the ectoderm.

8. The tentacles of Condylactis through their reactions exhibit marked polarity, ciliary and neuromuscular. The neuromuscular polarity disappears on narcotisation with chloretone. It is probably dependent upon the direction taken by the nerve fibrils which emerge from the sense cells. Where this direction has been determined, it is predominantly toward the proximal end of the tentacle.

9. The actinian tentacle, in contradistinction to such appendages as those of the arthropods or the vertebrates, contains a complete neuromuscular mechanism by which its responses can be carried out quite independently of the rest of the polyp.

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PEDAL LOCOMOTION IN ACTINIANS[1]

G. H. PARKER

ONE FIGURE

I. INTRODUCTION

That many actinians can creep with more or less activity by means of their pedal discs over the surfaces to which they have attached themselves, seems to have been known to the earliest students of these animals, but aside from brief references to the simple fact of creeping the literature contains very little concerning this activity. The chief exception to this statement is the short paper by McClendon ('06), in which the creeping of Metridium marginatum is briefly described, and the notes made by Osburn ('14) on the distances covered in creeping by this species and by Sagartia leucolena. It is the object of the present paper to take up this activity more fully than has been done heretofore and to show in what respects it is related to actinian organization.

The work was carried out for the most part on four species of actinians: Metridium marginatum Milne-Edw. and Sagartia luciae Verrill at Woods Hole, Massachusetts; and Condylactis passiflora Duch. and Mich., and Actinia bermudensis Verrill at Bermuda. I am under obligations to Dr. P. H. Mitchell, Director of the Laboratory of the United States Fisheries Biological Station at Woods Hole, and to Dr. E. L. Mark, Director of the Bermuda Biological Station, for many courtesies shown me while I was working at these stations.

In dealing with the subject of pedal locomotion it was my intention to find out how the direction of such locomotion is related to the axes of the actinians, what the mechanics of the locomotion is, and what structural conditions are present in the actinians whereby this form of locomotion is made possible. Of the three fundamental and mutually perpendicular axes of

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[1] Contribution from the Bermuda Biological Station for Research. No. 55.

this organism, I shall have occasion to refer to only two. These both lie in the plane of bilateral symmetry. One, which I shall call the *primary axis*, is the chief axis of the cylinder which the actinian typifies; the other, which I shall call the *secondary axis*, is perpendicular to it.

II. SECONDARY AXIS AND DIRECTION OF LOCOMOTION

In bilateral animals the chief or primary axis so commonly coincides with the direction of locomotion that it is natural to ask whether a like relation exists in the actinians, for, as is well known, many of these animals exhibit bilateral symmetry internally even though their parts seem to be radially disposed externally. The four species studied were all sessile rather than locomotor. Metridium crept rarely and slowly (Fleure and Walton, '07, p. 218, note that Metridium dianthus may move as much as 7 inches in a day), Sagartia moved frequently but still slowly, Condylactis with greater freedom and speed, and Actinia most freely of all.

As a preliminary step specimens of all these species were watched and when creeping was shown by any of them, a record was made of the direction of locomotion in relation to the secondary axis of the animal as indicated by the plane in which the mouth was elongated. Thus a large brown specimen of Metridium, whose pedal disc had a diameter of about 7 cm., was observed to creep up the vertical side of a glass aquarium for a distance of some 10 cm. and during the whole of its course the secondary axis was approximately at right angles to the direction of locomotion. In another instance a specimen crept upwards in a jar over a stretch of about 9 cm. with the secondary axis coincident with the direction of locomotion. In a specimen of Condylactis whose pedal disc measured about 13 cm. by 8 cm., the direction of locomotion also coincided with the secondary axis. In Sagartia a specimen with a pedal disc measuring 15 mm. by 8 mm. was seen to creep over a distance of 4 mm. with this axis in exact agreement with the direction of motion, though in a second specimen the secondary axis was observed to be almost precisely at right angles to the direction of creeping. In six other individuals the line of locomotion in each case was oblique to this axis.

These preliminary observations made it quite clear that the actinians under consideration not only do not creep invariably in a direction corresponding to their secondary axis, but that their directions of locomotion bear no simple relations to such axes. Is this relation constant for each individual, or does it change from time to time in the same animal? An answer to this question was sought in the two more easily controlled species, Actinia bermudensis and Sagartia luciae. Actinia bermudensis when placed in a large, flat-bottomed, glass dish is very likely to attach itself quickly to the glass surface and begin creeping. The directions of its movements are by no means constant. How diverse they may be can be indicated by the records from a single animal. Designating the direction of the secondary axis in this animal as north and south, the successive creeping movements made by it were found to be as follows: Five movements one after another were first taken in what would correspond to a westerly direction, then one to the northwest, followed by one to the north, after which the animal made three movements to the southwest, then three to the west, and finally two midway between west and southwest. All these movements were carried out without shifting the secondary axis from its original north-south direction.

Still more conclusive results were obtained from Sagartia luciae, which I have had the opportunity of working on since the publication of my preliminary note (Parker, '15). This species is negatively phototropic[2] and the direction of its movements can be controlled easily by changing the direction of the light. A monoglyphic specimen was induced by a beam of strong light to creep in the direction of its secondary axis. The light was then shifted through 90 degrees, and in about 10 minutes the animal had changed its course correspondingly but without turning its body. It was thus induced to creep at right angles to this axis. The light was next set at about 45 degrees to its first

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[2] Contrary to the statement made by Hargitt ('07, p. 280) I have found Sagartia luciae very responsive to light.

position and the actinian after a short interval began again to creep away from the light and without changing the direction of its secondary axis. Three other specimens were tested in essentially the same manner and gave similar results. In all cases new courses of locomotion in close agreement with the direction of the light were established in from 10 to 15 minutes after the change in the position of the light was made and the animals could thus be induced to creep at any angle to their secondary axis. In other words, locomotion in actinians is radial in character and is not limited by the structural bilaterality of these forms. This bilaterality, then, is not locomotor, as it is in most of the higher animals, but must be associated with some other general function. What this function is cannot be stated with certainty, but the fact that the bilaterality of the sea-anemones centers around the mouth which, though a single opening, is elongated and differentiated for simultaneous incurrent and excurrent streams, and thus serves respiration, the appropriation of food, and the discharge of excrement, suggests that these rather than locomotion are some of the activities whose influences have brought about the bilateral symmetry of the sea-anemones.

III. MECHANICS OF PEDAL LOCOMOTION

In all the actinians I have studied, locomotion was accomplished by a wave-like movement that passed over the pedal disc. This would begin at the rear edge of that organ and proceed thence to its front edge. Such movements are almost always accompanied by an elongation of the pedal disc in the direction of locomotion as observed by Osburn ('14, p. 1165). In Metridium these waves have been briefly described and figured by McClendon ('06), who ('11, p. 61) has also identified them in Cradactis. So far as I am aware, however, the details of this movement have never been very fully investigated.

In a specimen of Sagartia whose pedal disc had a diameter of about 4 mm. the waves could be seen coursing from the rear to the front as the animal crept over the level bottom of a glass dish. In 15 minutes 5 successive waves had passed across the disc and the animal had crept about 6 mm. The slowest wave required 2.5 minutes to traverse the disc, the most rapid 1 minute, the average time being 1.65 minutes. The distance progressed as a result of each wave was on the average 1.2 mm. Each wave began by a general contraction of the posterior edge of the pedal disc whereby that portion of the disc was lifted off the substratum and crowded toward the front. This wave of contraction gradually proceeded toward the middle of the disc and the posterior edge was then brought down on the substratum a little in advance of its former position. The wave now reached the anterior edge of the disc and, while the middle was being reattached to the substratum, the anterior edge, now freed, was advanced and finally brought down somewhat in front of its former position. Thus the passage of a single wave carried the whole pedal disc forward for a short distance and as a result the animal changed its location. It is doubtless the front portion of this wave that Torrey ('04, p. 204) speaks of in Sagartia davisi as a multicellular ameboid process by which this species could creep more than an inch an hour.

In Actinia bermudensis the pedal waves were quite like those seen in Sagartia except that they were of more considerable dimensions. In a specimen whose pedal disc measured 30 by 27 mm. the complete passage of a single wave required from 3 to 3.25 minutes and at each wave the animal progressed from 4 to 4.5 mm. In Metridium, whose pedal disc is about the same size as that of Actinia bermudensis, the locomotor wave passes over the disc, according to McClendon ('06), in the short interval of about a minute.

In Condylactis, because of its large size, the waves were more satisfactorily studied than in either Sagartia or Actinia. In a specimen whose pedal disc measured 130 by 80 mm., the waves passed over the disc in from 3 to 4 minutes and for each wave the animal progressed a distance varying from 5 mm. to as much as 17 mm. In another instance 10 waves were seen to pass in 30 minutes and the animal progressed in this interval 114 mm. Thus the average period of each wave was 3 minutes and the average distance advanced for each wave was 11.4 mm. As the wave passed over the pedal disc of Condylactis, it was easy to see in the region of activity that each part of the disc was successively lifted off the glass, advanced, and put down again. This was suspected to be the case in Sagartia and has been intimated for Metridium by McClendon ('06).

The accompanying diagram (fig. 1) illustrates the steps by which these waves may give rise to actual locomotion. At stage

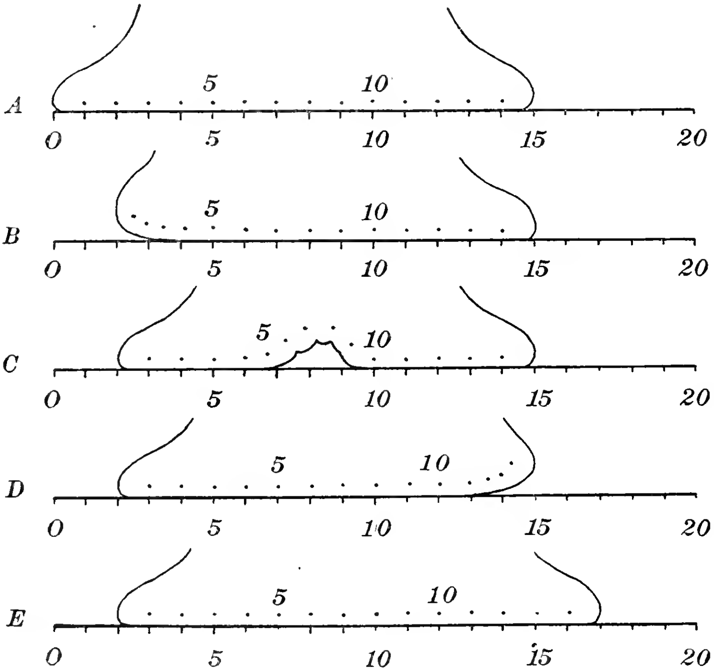

Fig. 1 Diagrammatic side-view of the foot of a creeping actinian illustrating the passage of a locomotor wave from one period of rest (*A*), through a period of activity (*B*, *C*, *D*) to a second period of rest (*E*). Fixed points on the substratum are numbered *0*, *5*, *10*, *15*, and *20*. Points in the actinian that at the beginning were opposite the fixed points *5* and *10* in the substratum are numbered also *5* and *10*.

A a pedal disc is supposed to be at rest on the substratum, and corresponding points in the disc and on the substratum are similarily numbered. At *B* the locomotor wave has made its appearance at the posterior edge which has been lifted off the substratum and moved forward. At *C* the wave has reached the middle of the disc and the posterior part has reattached itself in advance of its former position. At *D* the wave has reached the anterior edge, which is now beginning to be moved forward. At *E* the whole disc is at rest again but in a position in advance of its former situation.

I think there can be no doubt that this type of movement was observed by Gosse ('60, p. 81) in Sagartia pallida though somewhat inaccurately described by him. Gosse states that this species, which crept away from the light and covered as much as thrice its length in a quarter of an hour, accomplished this movement by pushing forward the front part of its pedal disc and attaching this portion, after which the hind part was loosened, drawn up to the front part, and reattached. This description, which agrees with that recently given by Fleure and Walton ('07, p. 218), implies a type of motion like that of a measuring-worm, and is probably a slightly inaccurate account of the wave movement seen by McClendon and me, from which it differs after all only slightly.

In all the creeping actinians that have come under my observation I have never noticed more than a single wave on the pedal disc at one time. In my experience a given wave runs its full course and completely disappears at the front edge of the disc before a second wave begins to form at the hind edge. McClendon ('06), however, states that he has seen two waves on the disc of Metridium at the same time. I know of no reason why this may not occur especially when the direction of creeping is well established.

The direction in which the pedal wave is propagated always agrees with that of the locomotion. The waves on the actinian disc may, therefore, be called direct waves to borrow a term introduced by Vlès ('07) for the waves on the foot of the gastropod. But this is not the only resemblance of the actinian wave to that on the gastropod foot. As the preceding description shows, the two movements are mechanically identical, for in the locomotion of the gastropod, as in that of the actinian, each point on the foot is successively lifted, moved forward, and put down (compare Parker, '11).

In another respect also the creeping of the actinian agrees with that of the gastropod. As Osburn ('14, p. 1165) pointed out for Sagartia, an actinian as it creeps leaves behind it a trail of slime much as a snail does. This slime is produced by the many unicellular glands in the ectoderm of the pedal disc and undoubtedly serves to increase the adhesion between the disc and the substratum. When the resting place of one of the more sessile actinians, like Metridium, is examined, it is usually found heavily coated with slime, which is often partly solidified into a membrane of a more or less brownish color. In assuming this relatively fixed condition the pedal disc of Metridium gradually spreads out over a comparatively large area and by the secretion of slime the actinian may anchor itself very firmly to the substratum. In this operation the region of most effective attachment is the edge of the disc rather than its center. Nevertheless the disc does not appear to act as a sucker, a fact which is probably correlated with the absence of a parieto-basilar muscle in this species.[3] Thus the pedal disc of Metridium, like the foot of the gastropod, may serve as a holdfast as well as an organ of locomotion (Parker, '11). In this respect, however, the disc must not be looked upon as a fleshy organ that simply adheres to the substratum in a purely mechanical fashion. It has often happened that the large actinians, Metridium and especially Condylactis, when in full locomotion, would meet with difficulty in loosening the active part of their discs from the substratum. Most of the disc would easily become free, but particular points would often continue to adhere to the substratum until after much straining they would suddenly break away. The impression made at the time was that these points of adhesion represented minute well localised organs of attachment, but whether such really exist in addition to the general surface of the disc I can not say.

IV. STRUCTURE OF THE PEDAL DISC

The parts directly concerned with the creeping of actinians are the muscles in the pedal disc and in the immediately adjacent region as well as the fluid contained therein. In Metridium,

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[3] In other species of actinians in which there are parieto-basilar muscles the pedal disc may act as a sucker as surmised by Piéron ('06), Hérouard ('11) and others.

as is well known (compare Parker and Titus, '16), all the muscles of the pedal-disc region are entodermic, there being no ectodermic muscles in this part of the animal. Next the supporting lamella of the disc and on its entodermic face is an extensive system of circular muscle fibers, the circular muscle of the pedal disc, covering the whole inner surface of the disc and arranged concentrically with respect to it. To the inner face of the pedal disc are attached in radial arrangement all the mesenteries; the larger ones extending from the outer edge of the disc to its center, the smaller ones reaching from the edge only part way to the center, and the smallest ones being limited almost to the edge itself. Each mesentery carries on its two sides and next its region of attachment to the disc slight muscle-bands, which extend from near the edge of the disc to or at least towards the center of this structure. These muscle bands, which are known as the basilar muscles, have therefore radial courses and cross the circular fibers of the disc at right angles. Beside the circular fibers and the radial fibers just mentioned, the longitudinal fibers of the mesenteries terminate in the disc, many of them passing almost perpendicularly from the disc into the mesenteries. It therefore follows that the pedal disc at most points, but especially towards its edge, may be said to be provided with three systems of fibers mutually at right angles to one another, the whole arrangement being strictly on a radial plan. The supporting lamella of the pedal disc like that of the wall of the column contains a rich supply of interlacing nerve fibers (Parker and Titus, '16).

The creeping movements of the pedal disc are carried out by the neuromuscular mechanism just described. As the locomotor wave begins at the hind edge of the disc, the initial contraction probably includes all three sets of muscles but especially the radial fibers and the mesenteric fibers. These muscles work on parts whose fluid contents are under some pressure from the general muscle tonus of the body as a whole.

As the wave passes over the pedal disc and approaches the front edge of that organ, this edge can be seen to be much distended by the pressure of its fluid contents. The walls of the edge are thin and bulge out between the mesenteries which serve as internal resisting supports and are marked by depressed lines on the surface. If one of these bulging faces is punctured by a needle, water will flow freely from it and the chamber will collapse for a time. It is thus clear that the projection of the front edge of the disc as the locomotor wave reaches it, is dependent upon the pressure of the contained fluid acting on the relaxed walls of that region. How considerable this pressure is has not been determined, but it is without doubt the chief factor in forcing the anterior edge of the disc forward. A small glass tube carefully inserted into the body of a large creeping Metridium showed an internal pressure in one instance of 5.3 cm. of water and in another of 6 cm. Both these pressures must be decidedly above the normal, for in both instances the insertion of the tube caused the animals to contract somewhat and thereby to increase their internal pressure. The mechanism of creeping, then, depends upon the action of the muscles of the pedal disc and its immediate vicinity on the fluid which is contained in the animal under a pressure of less than 5 or 6 cm. of water. This method of producing locomotion, without the participation of skeletal parts, has long been recognized in many invertebrates and is generally admitted for such organs as the foot of the gastropod.

Ever since the work of the Hertwigs ('79–80) it has been customary to assume that the normal neuromuscular activities of the actinian body were more or less under the control of at least slightly centralized nervous organs, which were believed to be located in the oral disc. To what extent are the creeping movements of the pedal disc dependent upon such oral centers? To answer this question experiments were carried out on Sagartia luciae. Fully expanded, attached specimens of this actinian were suddenly cut transversely in two with a pair of sharp scissors. The oral pieces thus cut off and carrying with them in each case the whole of the oral disc, tentacles, etc., were discarded. The attached pedal discs and remaining portions of the columns were held under careful observation. These contracted at the level at which they had been cut so as to look like an actinian normally withdrawn. They soon filled themselves with water and in 12 to 15 hours after the operation many of them were creeping about precisely as the whole animals did. A single record will illustrate this. One of the animals without its oral disc began creeping and was observed to carry out 4 movements in 16.5 minutes traveling in that period 7 mm. An animal with its oral disc intact that had been kept under similar conditions as a control carried out 4 locomotor movements in 22.5 minutes, travelling in that period 6 mm. As the differences between these two sets of records are no more than may be seen in any pair of normal individuals, the locomotion of the two animals may be regarded as essentially identical. Individuals without oral discs not only creep as whole individuals do, but they also attach themselves to a glass surface as firmly as do those with oral discs. Furthermore those without oral discs creep away from the light as consistently as do normal individuals. In fact, so far as the creeping is concerned, it is impossible to distinguish one class from the other except perhaps that the operated animals are somewhat less inclined to creep than the normal ones are.

The conclusion to be drawn from this experiment is that the pedal disc and its immediately adjacent parts contain all the neuromuscular mechanism that is necessary to creeping, in other words, this function is in no sense dependent upon the assumed nervous centers of the oral disc. These results are in entire accord with Loeb's investigations ('95, p. 418; '99, p. 34) in which he has shown that an Actinia equina from which the oral end has been cut off will creep more or less continuously on glass, and will attach itself firmly to a mussel shell just as a normal animal will. They are also in accord with Jordan's results ('08, '12) in which he has shown that the reflex excitability and muscle tonus of actinians is not under the control of superior nervous centers. They are quite at variance with such views as those expressed by Gosse ('60, p. 81), who in speaking of the creeping of Sagartia pallida states that "it was impossible to witness the methodical regularity of the process and the fitness of the mode for attaining the end, without being assured of the existence of both consciousness and will in this low animal form." In this respect the pedal disc is like an actinian tentacle which on being cut off will, if properly handled, carry out temporarily all the reflexes that it exhibited while it was a part of the animal as a whole.

The creeping of an actinian is by no means a simple process. Not only is a rather complex wave of locomotion made to pass over the pedal disc from one side to the other, but this wave may originate at any point on the edge of the disc and pass through its center to the opposite edge; in other words, the disc appears to possess potentially an infinite number of axes of locomotion. From this standpoint its strictly radial structure conforms well with its activities, for a system of circular and of radial fibers in a horizontal plane combined with a set of approximately vertical fibers gives just that structural combination necessary for unrestricted radial locomotion. The effective symmetry of the actinian pedal disc is, then, a locomotor symmetry for it is strictly radial; the symmetry of the oral disc, as already pointed out, is bilateral and is in no direct way connected with locomotion.

What it is that induces the formation of locomotor waves on any particular side of the pedal disc of an actinian, is not easy to discover. Probably many stimuli are effective in this respect. The fact that Sagartia and many other actinians creep away from light suggests that the light itself may stimulate the mechanism concerned with the formation of the locomotor waves, for in negative animals such as these the light falls most strongly on that face of the animal where the waves originate.

Sagartia likewise commonly creeps up the sides of glass jars and it will do this even when the top of the jar is closed and contains no air. Such a reaction would, therefore, seem to be of a geotropic kind and dependent perhaps upon the deforming pressure exerted on the lower edge of the pedal disc of this actinian when attached to a vertical support, for the body of Sagartia is slightly heavier than sea water and would tend to sag downward from a horizontal position. However this may be, some stimulus must be present to start from a given side the locomotor wave which then courses in a determined direction across the pedal disc to be followed often by others whose presence calls apparently for no more mechanism than is found in the relatively simple neuromuscular structure of this organ acting on the fluid retained under slight pressure in the adjacent body spaces.

V. SUMMARY

1. The direction of creeping of actinians is independent of their secondary axis. In a single specimen of Actinia or of Sagartia the direction of creeping may change from time to time without relation to the secondary axis. The bilaterality of actinians, therefore, is not locomotor as in most animals. It is probably respiratory.
2. Actinian locomotion is accomplished by a wave-like movement which progresses over the pedal disc in the direction of locomotion.
3. In a specimen of Sagartia with a pedal disc about 4 mm. in diameter, the locomotor wave coursed over its disc in an average time of 1.65 minutes and with each wave the animal progressed on the average 1.2 mm. In a specimen of Condylactis with a pedal disc 130 by 80 mm., the passage of a locomotor wave required on the average 3 minutes and the animal progressed for each wave on the average 11.4 mm.
4. In the actinian locomotor wave each point on the pedal disc is successively raised from the substratum, moved forward, and put down.
5. The attachment of the actinians studied to the substratum is due chiefly to adhesion heightened by the secretion of a thick slime rather than to a sucker-like action of the pedal disc.
6. The mechanism of locomotion consists of the circular muscle of the pedal disc, the basilar muscles, and the longitudinal muscles of the mesenteries, all of which act on the fluid-filled spaces in the pedal region of the actinian. The pressure thus generated is not above that of 6 cm. of water.
7. Creeping can be accomplished by an actinian from which the oral disc has been cut away. Hence the pedal portion of actinians, like their tentacles, contains a neuromuscular mechanism sufficient for its own activity.

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By Hovey Jordan

BERMUDA BIOLOGICAL STATION FOR RESEARCH, AGAR'S ISLAND, BERMUDA[1]

Communicated by E. L. Mark and read before the Academy, November 14, 1916

An unusual, but orderly, arrangement displayed by several groupers or hamlets (a marine fish, *Epinephelus striatus* Bloch), confined in a cage through which flowed a current of fresh seawater, called my attention to their peculiar rheotropism. The tails of all were directed *into* the current. When this was shut off their arrangement became promiscuous, indicating that their novel posterior orientation was a true rheotropic response.

This phenomenon led me to investigate in detail the behavior of these fishes both in groups and individually, in order to determine whether this posterior orientation to a current—which, so far as I have been able to learn, is undescribed—is a normal response of the grouper. For this purpose a number of fishes were placed in the cage and a record was made of the positions which they assumed at two-minute intervals. These observations were made both at night and during different parts of the day. In one record, which is fairly typical, the positions of each of 7 fishes at 30 successive intervals—in all 210 observations—were noted. Of the 210 observations 141 showed the fishes to be tail into the current (posterior orientation), 67 side to the current (lateral orientation), and only 2 head into the current (anterior orientation). In order to determine whether posterior and lateral positions indicate different responses by individual fishes, or are simply phases of one reaction, fishes were studied singly. For this I used a small aquarium (30 × 20 inches) across which a moderate current of water flowed diagonally. Each of the fishes tested remained most of the time near the inlet in the region of the strongest current. It assumed in succession slightly different positions, chiefly by rotating the long axis of the body through an arc of 90° to 180° around its own center, which preserved a comparatively fixed position in the axis of the current, so that either one side of the body or the tail was at any given instant directed toward the current, into which, however, the head was never pointed. After assuming approximately a dozen such temporary positions, which required about three or four minutes, the grouper tailed directly into the current and remained in this position for about three minutes. It then began a second series of changes similar to the first. In this sequence of positions it is perhaps most natural to regard as a single period the time occupied from the beginning of one set of 'swinging motions' to the beginning of the next; thus the posterior orientation, which is of longest duration, is the last phase of the orienting process. A characteristic reaction, then, of *Epinephelus striatus* is posterior or lateral orientation to a current. Since in a majority of cases the orientation is posterior, and since this is maintained longer than any other position, it is a fair inference that this is the significant reaction.

Various regions of the body were explored with a localized current (1/28 liter per second) directed through a long glass tube, the experimenter being invisible to the fish. The following areas were found to be sensitive, but the response varied in promptness. Stimulation of the lips (if prolonged it causes a relatively violent reaction) brought forth a response in 7 seconds; the caudal fin in 16 seconds; the dorsal fin in 22, the cheek and operculum in 25, and the side of the body in 30 seconds. From these observations it is clear that the lip region is much the most sensitive part of the surface of the body, and the possibility is at once suggested that the posterior orientation of the fish is a reaction which serves to protect this region from the action of the current. This seems the more probable from the fact that prolonged stimulation of this region by the current employed in the experiment always caused a rather extraordinary and violent reaction.

Several end organs have, at one time or another, been regarded as the receptors in the case of rheotropic responses: lateral-line organs[5] (Schulze, '70); the organs concerned in response to pressure[7] (Verworn, '97, p. 445ff., barotaxis), and the ear[6] (Tullberg, '03).

Two other views have been advocated, first, that it is the tactile corpuscles which are stimulated by currents[3,4] (Parker, '03a, '03b); secondly, that it is chiefly the eyes which are stimulated, this being due to the transportation of the fish through the water. According to this view[2] (Lyon, '04), rheotropic reactions are chiefly optic reflexes, which serve to compensate the apparent motion of the visual field. This is an indirect effect, a direct stimulation being produced only when the fish is in contact with some part of the solid environment. This, in the case of blind fishes, Lyon thinks acquaints the animal with its transportation and a compensatory swimming results.

In studying the question of rheotropic end organs, observations—to be described elsewhere—were made which confirm the idea that sense cells of pressure and equilibration are unaffected by water currents. The lateral-line organs and the eyes, which can be rendered functionless by appropriate operations, are also unaffected. The skin was next removed from certain body areas and the underlying tissue was found to be insensitive to localized currents. This indicates that the rheotropic end organs are cutaneous; of these only the tactile corpuscles were found to be of significance. This is shown by the following experiments. Under normal conditions stimulation of the lips by a glass rod produces a very violent negative reaction, and so, too, does a current of water of the sort just described. The lips of a normal fish were anaesthetized by the application of a 0.1% solution of cocaine. As a result the reaction (and assumably the sensitivity) to tactile stimulus disappeared completely, and also the reaction to the water current. Not only that, but also the parallelism between the effects of the two sorts of stimuli at any instant, both during the gradual benumbing of the lips by the reagent and during their progressive recovery from insensitivity, seemed to be complete. These facts indicate that the end organs of tactile sensitivity serve also as the essential and organs of rheotropic sensitivity. Other sensory cells, while they may in some cases be affected by currents, apparently play no necessary part in the reaction here described.

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BY W. J. CROZIER.

Contributions from the Bermuda Biological Station for Research, No. 57.

A study of the supposed "warning" coloration of brilliantly pigmented nudibranchs as represented by *Chromodoris zebra* Heilprin, has incidentally made clear the previously unknown significance of the "white conical bodies" which occur on the posterior ventral surface of the mantle of this species and give it a beaded appearance. Since white nodular structures of a presumably similar character have been noted upon the mantle edge of other tropical nudibranchs, the function of these organs as worked out in *C. zebra* is probably identical among all the species in which they occur.

The bodies in question are in fact glands, which store a special secretion concerned in protecting the nudibranchs from the attacks of preying enemies. They are, in a functional sense, comparable to the repugnatorial glands of the littoral pulmonate Onchidium, although their mode of action is different. They occur, usually 5, 6 or 7 in number, immediately over the "tail." In some instances 10, 12, and even as many as 19, of these organs have been noted. The manner of their distribution strongly suggests that 5, and in some cases 7, specialized regions exist which give rise each to one of the conical bodies. The central gland of the 5 or 7 is situated in the median plane of the body. It is significant that the increased number of the organs, when they exceed 7, is usually (if not invariably) associated with some injury, such as would be occasioned by the bite of a fish, which has removed a portion of the gland-forming area of the mantle.

Not all the bodies on a single animal are of the same size, one or more being sometimes quite minute. The definite pattern according to which they are arranged is preserved even in cases where one or more of the glands is totally suppressed.

Each of the glands is provided with a pore. In rare cases two pores have been found upon a single gland. The pores are surrounded by a sphincter. When Chromodoris is violently disturbed in any way, its consistent reaction is to withdraw the gills and rhinophores, to erect the lateral edge of the mantle, and to turn under, ventrally, the posterior part of the mantle bearing the glandular organs. At the same time the glands become turgid, through the contraction of their muscular investment, the pores being then more prominent. If the irritating stimulation is continued, there issues from the pores of one or more of the glands a white creamy secretion, which is not dissolved by sea water. It is composed mainly of globules of an oily substance. The secretion is not acid, but is neutral to litmus.

When the glands are stimulated individually with induction shocks, they respond by pouring out their secretion, and the same reaction occurs, on stimulation, when the portion of the mantle which bears them is detached from the rest of the animal.

Chromodoris behaves with reference to these organs in such a way as to point to their importance in the animal's economy. The characteristic ventralward inbending of this portion of the mantle, so different from the boldness with which its lateral borders are thrown into prominence when the creature is disturbed, inevitably suggests a reflex of a protective kind. The nature of the conditions which determine their discharge leads one to regard the glands as repugnatorial in function. Careful study of the results of feeding these mollusks to fishes and various invertebrates has demonstrated that these bodies cannot, however, represent the sole source of offensive secretions. A repulsive material, histologically and microchemically resembling that found in the conical glands, constitutes in fact part of the secretion which proceeds from the whole integument of Chromodoris, but particularly from the lateral portions of the mantle. It is noteworthy that in many individuals there are to be observed, especially over the region of the mouth and tentacles, minute white bodies occurring on portions of the ventral mantle surface remote from the conspicuous white papillae. These bodies also give rise to the white secretion.

Such facts lead one to consider that the glands at the posterior end of the animal are merely the expression of a specialized development of the repugnatorial function which is the common property of the whole dorsal and lateral integument. The exposed location of the papillae also negatives the supposition that the glands may be the primary seats for the elaboration of the repugnatorial material, to be secondarily transported to other regions of the animal's surface. As a matter of experimental test, these nudibranchs when totally deprived of the beaded area of the mantle remain unimpaired in their ability to develop a protective distastefulness for fishes and invertebrates.

The repulsive character of the contents of the glands is readily established by controlled feeding tests in which food fragments are smeared with the secretion. Such morsels are invariably rejected. It remains doubtful, however, if this emulsion of substances represents the only repugnatorial material possessed by Chromodoris. It seems possible that the oily element of the secretion is particularly involved in the production of the curiously penetrating odor which the nudibranch emits, and that some other substance is also concerned in determining the general distasteful quality.

Incidentally, the glands cannot be implicated in any mutual attraction between individuals at the time of pairing, for animals from which the glandular equipment has been completely removed, are found to mate readily and deposit normal egg masses.

I have commented above on the suggestive appearance of protection evidenced by the inturning of the posterior beaded border of the mantle. A closer analysis shows, however, that any protection which is in this way afforded to the conical glands is purely incidental. For if the projecting "tail" of the nudibranch is stimulated (as with induction shocks), the beaded portion of the mantle is not rolled under upon itself, but is spread out so that the openings of the glands point in the general direction of the irritated area. Their discharge under these circumstances may occasionally be seen. I therefore believe that the ventralward inflection of the gland-bearing portion of the mantle is primarily a reaction having to do with the normal discharge of the glands. When the nudibranch is attacked at the side, or anteriorly, the glands are thus given an opportunity to discharge a part of their contents in an appropriate direction.

A full account of these observations will be published later.

Agar's Island, Bermuda.

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No. 58.

A CASE OF REGENERATION IN PANULIRUS ARGUS.

By A. C. Walton.

From The American Naturalist, Vol. LI, No. 605.

CAMBRIDGE, MASS., U.S.A.
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A CASE OF REGENERATION IN PANULIRUS ARGUS[1]

The occurrence of regenerative processes in the crustacea has been a matter of record for a number of years, but the instances have been mostly confined to the regeneration of appendages and portions of the nervous system. Observations on the regeneration of portions of the exoskeleton of the trunk are far less numerous. The present observations on the regeneration of a portion of the rostrum of *Panulirus argus*, the common crayfish of the Bermuda Islands, were made during the summer of 1916 at the Bermuda Biological Station.

Panulirus argus when full grown is about 14 to 16 inches in length. It lacks chelipeds, their place being taken by the ordinary type of walking appendage. None of the walking appendages is provided with nippers, all being tipped with a single hook, as, *e. g.*, in the fourth pair of appendages of the crayfish *Cambarus*. The rostrum of *Panulirus*, instead of being a single median projection, consists of a pair of long (30–35 mm.), sharply pointed spines, slightly compressed laterally, and growing out from the carapace just posterior and slightly dorsal to the base of the eye-stalks.

The animal in question was a half-grown male, eight and one half inches long. When caught, June 20, the left spine (compare figure and explanation) of the rostrum was entirely missing. The carapace around the base was jagged and rough, as though the break had been recent; but a thin, soft membrane had

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[1] Contributions from the Bermuda Biological Station for Research, No. 58.

formed across the surface of the break. Five days later, June 25, the protecting membrane had hardened, so that it could not be dented with the point of a scalpel. No further change could be noted until after the molting, which occurred four days later, June 29. The casting occurred at night, and the next morning the new shell showed no signs of any wound. By one o'clock a very slight hump appeared, and by ten o'clock at night a little rudimentary spine 2 mm. in length had formed. The next morning another millimeter had been added to its length. Meantime the normal spine had increased 1.5 mm. in length. No further growth followed before the new shell had hardened.

FIG. 1. From a photograph of the left side of the head region of *Panulirus argus*, showing (*norm.*) the normal, and (*regn.*) the regenerated rostral spine. As the figure is reproduced from a photographic print, the picture is reversed, the right spine appearing like a left one.

Sixteen days later, July 15, another molt occurred. As before, the old shell was cast at night and by the following morning the regenerating spine had added 2 mm. to its length, being now 5 mm. long. By the next evening all growth had been stopped by the hardening of the new shell, but the total length of the spine was at this time 7 mm. The spine now showed a sharp point and also a slight lateral compression like that of the normal spine. At this casting the normal right spine added 1 mm. to its length, showing that, while the whole animal was growing, the regenerating part was increasing at a much faster rate than other parts.

Thus in the period of twenty-seven days during which the animal was under observation, it had undergone two molts and had regenerated a missing rostral spine of normal form, 7 mm. in length, while the normal spine had added 2.5 mm. to its length in the same period. These results show that the period between molts for this animal under laboratory conditions is sixteen days; that a rostral spine of normal form can be regenerated; and that the rate of this regeneration was nearly three times the rate of normal growth of a similar spine during the same period.

A. C. Walton

Harvard University

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No. 59.

ON THE PERIODIC SHOREWARD MIGRATIONS OF TROPICAL NUDIBRANCHS.

By W. J. Crozier.

From The American Naturalist, Vol. LI, No. 606.

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ON THE PERIODIC SHOREWARD MIGRATIONS OF TROPICAL NUDIBRANCHS[1]

MANY northern gastropods, including nudibranchs, are well known to exhibit the habit of congregating in shallow water along the shore at their time of breeding. This has been commonly interpreted as the result of migration from deeper water at the approach of the egg-laying season. Certain species, at any event, are from time to time found in great quantity at shore stations which they do not frequent at other periods, and field observations have apparently established beyond a doubt that this inshore appearance is closely connected with mating and oviposition. The migration into shallow water, or other means which accomplishes the shallow-water flocking in these cases, may be regarded as a device which insures the concentration of individuals within a relatively small area, thus tending to make more certain the chances of pairing in a large number of instances, as well as a method of determining favorable conditions for larval development.

Collectors of nudibranchs who have worked in tropical waters have also reported cases which at first sight seem to afford additional examples of the coincidence of the spawning period with appearance in great numbers in the littoral zone (*e. g.*, Crossland, quoted by Eliot, 1904, p. 87). While engaged in working along the shore during a period of some days or weeks, it is

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[1] Contributions from the Bermuda Biological Station for Research, No. 59.

noticed that a certain species of nudibranch, until then found sparsely, if at all, suddenly begins to occur in abundance. It is also observed that at this time these nudibranchs are depositing eggs in the field, or that they pair readily and lay egg strings when kept in aquaria. The inference which has been drawn in such cases, namely, that the appearance in shoal water is in some way intimately related to the mating process, seems legitimate enough.

But I have observed at Bermuda certain facts regarding the normal migrations of a member of the typically tropical genus *Chromodoris* which, it seems to me, cast considerable doubt on the theory that this species, *C. zebra* Heilprin, moves into shallow water for the purposes of mating and egg deposition. The facts in this case, so far as they have been observed, are briefly as follows:

It was necessary to obtain considerable numbers of *C. zebra* for use in experimental work (Crozier, 1916[a], 1916[b]); consequently collections were made at short intervals (every day during some months) over the period from August, 1915, to October, 1916. I had had occasion, also, to note the occurrence of this species in the summers of 1913 and 1914. In June, and during the early part of July, *Chromodoris* was found in great abundance upon the "eel grass" in certain tidal "creeks" (Fairyland Creek, Millbrook Creek). Subsequently, in the last two weeks of July and in August, they became very scarce in such places, although a few could almost always be discovered by careful searching. At other times of the year a supply of the animals was obtained on hard, open bottoms in somewhat deeper water (1 to 2 fathoms, at low tide), in places where, I am certain, they would never have been seen during ordinary shore collecting. Occasionally, however, as was noted particularly in December, 1915, *Chromodoris* was abundant along the rocky shores of smaller islands, ranging well up to low-water level.

It seems clear enough that in *Chromodoris zebra* there undoubtedly does occur from time to time a movement of numbers of individuals toward the shore. But there are several facts which sharply contradict the view that this migration is connected with reproduction. The nudibranchs pair in the laboratory and lay strings of fertile eggs at all seasons of the year (cf. also Smallwood, 1910), and not merely at the times when they are abundant near low-water level. Moreover, I have obtained the egg masses in dredgings at every season of the year; hence we may regard the fact of egg laying at all seasons under laboratory conditions as of significance in this connection. The eggs, which are quite characteristic in appearance, and hence easily identified, have been collected in depths of eight fathoms and more. Large individuals of *C. zebra* are likewise not uncommon at these depths; in fact, the first ones to be described were dredged from ten fathoms in Harrington Sound (Heilprin, 1889, p. 187). A further point of considerable significance is found in the fact that these nudibranchs, unlike *Elysia* and certain other species, do not appear to deposit any egg masses upon the "eel grass" on which the animals occur in such great numbers throughout the early summer. The egg strings found in the field are invariably attached to rocks, or to the shells of *Arca noe,* the "mussel" with which the adults are frequently associated. The gelatinous egg-ribbons (cf. Smallwood, 1910) are quite large, measuring usually 120 to 150 mm. long by 15 to 17 mm. broad, and are much too heavy to be supported by a blade of "eel grass," as can readily be determined by trial. It is only rarely that an egg mass has been obtained in shore collecting.

The migration of *C. zebra* into shallow water cannot, then, be directly connected with reproductive activities. Since, in the laboratory at least, they deposit eggs usually within twenty-four hours after pairing, it does not seem to me probable that these nudibranchs pair to any great extent during the time which they appear to spend in the tidal "creeks"—no eggs, as stated, having been collected from among the "eel grass," nor were any ever obtained on the muddy bottoms of these "creeks." *Chromodoris* seems to require a firm, hard substratum for the attachment of its egg-ribbon. If individuals obtained in quite shallow situations are kept singly in aquaria they sometimes deposit after several days fragments of egg-jelly containing several dozen unfertilized eggs. while they almost invariably pair readily when given the opportunity. Nevertheless, it should be stated that the nudibranchs usually do not occur singly, two or three being commonly found within a space of several square meters even when the total number of individuals in a given area is small; and I am well aware that laboratory findings with regard to breeding habits are liable to be misleading. The established fact of egg production throughout the year in deep water is, however, good evidence that the periodic (or intermittent) abundance of this nudibranch in shoal situations can have little if any relation to oviposition.

It might at first be suspected that the periodic shoreward movement represents the phylogenetic persistence of a well-defined habit possessed by not distantly related northern species. From this standpoint, reproductive functions in *C. zebra* might be conceived of as having become dissociated from the habit of migratory periodicity, since in warmer seas, where the seasonal alteration in physical conditions is reduced to a minimum, it is well known (cf., for example, Semper, 1881, p. 135) that many forms have no specially restricted time for breeding. However attractive such a speculation may appear, it is eminently more satisfactory to regard these periodic littoral appearances of tropical nudibranchs as being controlled by definite physical influences in each individual case. Such directing causes would not necessarily be always the same for each periodic occurrence of the animals in shallow water. Although shoreward migration and egg laying are closely connected in northern forms, it is still probable that physical circumstances in the sea immediately control the migrations even in this instance also.

I have purposely refrained until now from discussing certain minor fluctuations in the littoral abundance of *Chromodoris* which are, nevertheless, important in connection with the idea that the supposed "migration" at certain times into very shallow water is, after all, only the unrestricted expression of a tendency to upward movement—negative geotropism. It has been mentioned that during the greater part of the year *Chromodoris* was collected in 1 to 2 fathoms. But after storms of some severity they were to be had only in much deeper water. The nudibranchs undoubtedly move into deep, quiet places when the surface is greatly disturbed. Just what their behavior is under these circumstances can not be stated from direct observation, for obvious reasons; and for several days, or even for a week after a severe blow, the water in the sounds and bays remains so roily that it is impossible to see the bottom. But I have frequently observed individuals creeping up from deep water after the sea has become quiet and transparent. As regards the bearing of these facts upon the major flocking into the littoral zone, which occurs in early summer, it is to be noted that the mere continuance of quiet, still weather is not enough to determine the abundance of *Chromodoris* in the tidal "creeks," since they disappear for the most part before the calm summer season is half over. The occurrence of individuals in deep water, together with field observations of specimens which were engaged in creeping downward on the sloping sides of rocks and reefs, leads me to doubt very much that any form of geotropic irritability exerts a preponderant control over the normal behavior of these animals. My observations strongly suggest, however, that there does occur to some extent (in appropriate places) a diurnal vertical movement of *Chromodoris*, which is directly determined by the positive phototropism of these nudibranchs.[2]

Specimens of the species known as *Chromodoris roscapicta* Verrill (there is some doubt that it is really a *Chromodoris*) have been found in littoral locations, only in the summer time, but this type is not sufficiently abundant to make possible a testing out of ideas concerning its migratory movements.

The point which I wish to emphasize most is the uncertain nature of conclusions having reference to the normal behavior of animals inhabiting the warmer seas on the basis of comparisons with superficial features of the movements of their relatives in colder waters. In the case of *Chromodoris zebra,* it seems to me definitely established that the periodic flocking of individuals into very shallow water has no immediate connection with reproduction.

On Jan. 10th, 1917, I found that *C. zebra* was crowding in great numbers into the entrance of Fairyland Creek. During the next few days they became very abundant indeed, so that on one occasion 230 of them were picked up in less than an hour's collecting. On Jan. 12 I began to find egg masses attached to certain sponges, matted algæ, mangrove roots, and sundry mooring stakes in the "creek." I had not before found any in this place, as stated above. The nudibranchs were observed in copulation, and great numbers of egg-masses were found. The attachment of the egg-masses was most frequently to some firm object. Within the week Jan. 10–17 they began to disappear, and after a fairly severe storm which came at that time very few were obtainable in the "creek." This occurrence seems to form a good

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[2] I am anticipating here the statement of certain facts regarding the responses of *C. zebra* which were established in this laboratory several years ago by Dr. L. B. Arey (*cf.* also Crozier, 1916^c).

instance of shoreward movement coupled with reproductive activity, but the fact remains that the nudibranchs do breed abundantly at other times and in much deeper water.

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Agar's Island, Bermuda.

W. J. Crozier

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By R. P. Wodehouse.

From The Journal of Biological Chemistry, Vol. XXIX, No. 3.

CAMBRIDGE, MASS., U.S.A.
April, 1917.

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DIRECT DETERMINATIONS OF PERMEABILITY.

By R. P. WODEHOUSE.

(*Contributions from the Bermuda Biological Station for Research, No. 60, and from the Laboratory of Plant Physiology, Harvard University, Cambridge.*)

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It is desirable to determine directly the penetration of substances into the living cell, but in most cases this is difficult or impossible. In order to make such direct determinations it is necessary to compare the composition of the cell sap with the composition of the liquid in which the cell is immersed. In the case of tissues this is impossible, because in crushing the cells to obtain the cell sap the latter is contaminated by admixtures of material from the intercellular spaces as well as altered by chemical action and adsorption. It is therefore necessary to employ individual cells and to extract their cell sap without opportunity for contamination or change.

Most cells are too small to yield satisfactory results by this method. The writer, however, has been fortunate in having an opportunity to experiment with the marine alga *Valonia,* which has individual cells so large that it is easy to get from a single cell enough sap upon which to make chemical tests. Cells of the average size yield from 1 to 2 cc. of sap, and it is not unusual to obtain cells which yield as much as 5 cc.

The cells were removed from the sea water, rinsed in distilled water, dried with filter paper, and then punctured with a needle. On pressing the cell wall the sap squirted out and was collected. This sap is contained in the large central vacuole of the cell (or cœnocyte).

Upon examination the cell sap was found to differ, in most cases, materially from sea water. The sap was taken from a few plants and tested qualitatively for the presence of some of the salts of sea water.

As for the metal ions of sea water, sodium could easily be demonstrated within the cell by allowing some of the sap to evaporate on a watch-glass when crystals of sodium chloride were seen to be formed. The presence of calcium was easily demonstrated. When a saturated solution of ammonium oxalate was added to the cell sap a white precipitate was produced which was soluble in hydrochloric acid but insoluble in acetic acid. This precipitate was washed in acetic acid and water and when dissolved in a small amount of hydrochloric acid gave an unmistakable flame test for calcium.

A similar condition, however, was not found to hold for magnesium. In sea water this can easily be demonstrated by precipitating with any of the fixed alkali hydroxides (*e.g.*, NaOH) forming $Mg(OH)_2$, which is white, gelatinous, and insoluble in excess of the reagent but readily soluble in the presence of ammonium salts, and from such solution can readily be precipitated by the alkali phosphates (*e.g.*, Na_2HPO_4) in the form of magnesium ammonium phosphate. When this method was tried on the cell sap, however, only the merest trace of a precipitate was obtained by the addition of NaOH and, though this disappeared upon the addition of ammonium sulfate, the addition of disodium phosphate to the solution would not cause the precipitation of any magnesium ammonium phosphate. This shows that, though magnesium is probably present within the cell, it does not exist in nearly as high a concentration as in sea water.

Exactly the opposite obtains in the case of potassium. In sea water the concentration of potassium is so low that no precipitate was produced by the addition of picric acid, and the dried residue gave only a doubtful flame test. With the *Valonia* sap, however, the dried residue showed an abundance of potassium by the flame test; when picric acid was added to the sap long acicular crystals settled out, and when these were dried and touched with a hot needle they detonated, giving an unmistakable potassium-colored flash, showing that these crystals, formed by the addition of picric acid, were potassium picrate. From this it is plain that there is a considerably higher concentration of potassium within the cell than without.

The *Valonia* sap gives an abundant precipitate with chloroplatinic acid. The solution was heated to complete the reaction and when allowed to cool, the precipitate formed at room temperature and could be only slightly increased in amount by cooling to zero. Upon examination with the microscope this precipitate was found to consist mostly of octahedral crystals, the rest being made up of crystals of other forms but obviously of the same material because similar crystal forms were found in the precipitate in the control test with chemically pure potassium oxalate. This test seems to me to be conclusive for the presence of potassium. Its abundance in the sap is shown by a control test done on the Bermuda sea water. Keeping everything exactly the same it was impossible to get the potassium chloroplatinate crystals to form even by cooling down to zero. Small crystals could be caused to form only by evaporating the mixture nearly to dryness and adding several volumes of absolute alcohol. The conclusion arrived at from the picric acid test is thus confirmed.

The proportions of the four kations Na, Ca, Mg, and K, could not be determined quantitatively on account of the limited amount of material available at the time when the work was done. This is very important from the viewpoint of antagonism and the author hopes to make it the subject of further investigation.

When the anions of sea water were tested for the presence of chlorides they were indicated in all the tests made by the copious precipitate produced by the sap with silver nitrate. Barium chloride, however, failed to give any precipitate with the sap, thus showing the absence of sulfates. Nevertheless, barium chloride gave an abundant precipitate with the sea water from which the plants had been taken. Occasionally a cell was found which showed the presence of sulfate in the cell sap by the barium chloride test. Upon further investigation it was found that cells which were obviously dead always showed the presence of sulfate and that those which appeared to be in an unhealthy condition frequently gave a positive test. The cells which seemed to be healthy rarely gave any precipitate at all with barium chloride. Accordingly the following series of tests was made to determine if the presence of sulfate was associated with death or injury of the cell. On holding the cells up to the light the healthy ones were seen to have a uniform green color over the entire surface, while cells which are described below as in poor condition had a mottled appearance, or the protoplasm appeared to be slightly shrunken, or else the cells, when held between the thumb and finger, could be felt to lack the normal turgidity.

In each case the description of the cell was written down before the test was made, in order to avoid subjective error.

No.	Description of cell.	$BaCl_2$ test.
1	Largest cell found (over 1 inch long).	No ppt.
2	Large, dead; protoplasm dead and shrunken.	Ppt.
3	Almost as large as No. 1; in good condition; old.	No ppt.
4	Small, average size, apparently healthy.	“
5	“ “ “ “ “	“
6	“ “ “ “ “	“
7	“ “ “ “ “	“
8	Large, but healthy.	“
9	Large; not in good condition but apparently still alive.	Ppt.
10	Appears to be in poor condition; not quite turgid but apparently still alive.	“
11	Much like No. 10.	No ppt.
12	Average cell in good condition.	“
13	“ “ “ “ “	“
14	Large and old but in good condition.	“
15	Small cell apparently healthy.	“
16	“ “ “ “	Ppt.
17	Average cell in good condition.	No ppt.
18	An old cell but apparently healthy.	“
19	Normal, average size.	“

Besides these cells, which were taken as nearly as possible at random, thirty-six other cells were chosen as being undoubtedly healthy, and of these only one showed the presence of sulfate. From experience it is possible, by inspection, to be almost always, though never absolutely, certain which cells are going to show the presence of sulfate.

From this it seems evident that sap of live and healthy *Valonia* cells does not contain free sulfate in large enough quantities to give a visible precipitate with barium chloride. It is also equally certain that when the cell dies sulfate enters, and it follows from this that the presence of sulfate in the cell indicates injury or death, even though no other manifestations are visible.

In order to preclude the possibility that sulfate was present, but in some chemical or physical union which prevented it from reacting with barium chloride, *Valonia* sap which had been shown to give a negative test with this reagent was boiled with nitric acid of several different concentrations, in order to break up any such possible union, and tested again. In each case, however, the test for sulfate was negative.

In order to test the matter still further, some of the sap was incinerated in a porcelain crucible. Upon incineration it showed the presence of a great deal of organic material, which left a deposit of carbon, but upon being boiled with HCl and incinerated again this was removed and the residue was completely soluble in water. The sea water, on the other hand, showed no organic material and proved to be largely insoluble in water after the same treatment. The soluble part, however, gave a copious white precipitate with barium chloride, while the *Valonia* sap after incineration with HCl gave just a trace, scarcely enough to be visible.

The conclusion from the above experiment is that there is little or no sulfate within the vacuole of the normal *Valonia* cell. Consequently, since there is an abundance of sulfate in the surrounding sea water, the semipermeable protoplasmic membrane must possess a selective permeability which renders it impermeable to sulfate as long as it is alive. This, however, is lost immediately upon death.

It is of course possible that sulfate may penetrate the outer plasma membrane into the protoplasm without being able to penetrate the vacuole membrane into the vacuole, but upon this point the experiment throws no light.

In order to test for permeability to nitrates, some cells were placed in sea water to which enough potassium nitrate had been added to give a good nitron test. After 24 hours the cells were still alive (they remained alive for several days when replaced in sea water) and showed the presence of nitrate within by the nitron test. The same was true of sodium nitrate. But it appeared upon examination that the control cells in normal sea water also showed the presence of nitrates by the nitron test. Sea water did not show the presence of nitrate by the nitron test. It is therefore evident that the nitrates within the cell must have penetrated through the plasma membrane, but this may have taken place wholly or in part before the nitrates were added to the sea water.

The mechanism by which nitrates and potassium are stored within the cell so as to remain at a higher concentration than in the surrounding sea water deserves further study.

It is of interest that the cell wall acts as an osmotic membrane but possesses no selective permeability. Dead cells are often turgid even though the protoplasm has shrunken away from the cell wall. These cells when put into a hypertonic salt solution almost immediately become flaccid, and when replaced in sea water or in fresh water they again become turgid. However, if dead cells are placed in water containing nitrates, nitrate can be demonstrated within them shortly afterwards. If living cells are killed and then replaced in sea water, sulfate can soon be shown to be present inside. This shows that salts can pass more or less freely through the cell wall and yet it offers sufficient obstruction to enable it to act as an osmotic membrane.

The writer takes pleasure in expressing his thanks to Professor E. L. Mark for the use of the facilities of the Bermuda Biological Station, where this investigation was made, to Professor W. J. V. Osterhout for his interest in the problem and many helpful suggestions, and to an unknown friend who assisted in bearing the expenses of the Bermuda trip.

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Occurrence of a Holothurian new to the Fauna of Bermuda.
By W. J. CROZIER.

(*Contributions from the Bermuda Biological Station for Research.*—No. 61.)

THE West-Indian affinities of the Bermudan fauna and flora (Britton, 1912, p. 193) have been evident to every student of these regions; yet, as Pilsbry (1900, p. 494) remarks in considering the Pulmonates, there is "abundant evidence of what we call chance, or the rigorous selective action of an over-sea journey, in the Bermudian assemblage." Continued collecting is disclosing further additions to the marine population in the shape of species identical with well-known West-Indian forms *. In one such case, which is the subject of this note, it seems to me that the addition may legitimately be considered as of recent date.

The pedate Holothurians of Bermuda waters have been collected ever since 1888 by Heilprin, Verrill, Clark (1901), and others. Each of the five species previously reported (*Cucumaria punctata*, *Stichopus möbii*, *Holothuria surinamensis*, *H. captiva*, and *H. rathbuni*) is well represented in the West-Indian area. Certain conspicuous Antillean types have, however, been lacking in the Bermudan collections; *Actinopyga* and several species of *Holothuria* are in this category †.

I have had occasion to examine with care several thousand specimens of *Stichopus möbii*, Semp.—with which, on superficial examination, *Actinopyga* might conceivably be confused,—and have, indeed, given particular attention to Holothurians collected at many points in Bermuda. No unusual specimens were observed until July 3, 1916, when there was secured from a depth of about 6 feet beneath low water, in the channel entrance to Hungry Bay (on the exposed south

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* Among the Enteropneusta, for example, of which an illustrated account is in course of preparation, at least two of the four or more species which I have found occur also in the Bahamas and at Jamaica, as well (probably) as at other stations in the West Indies.

† Of the five apodous species found here (Clark, 1907), only two (*Chirodota rotifera* and *Synaptula hydriformis*) are typically West-Indian, while two others (*Leptosynapta inhærens* and *L. roseola*) are northern forms; the remaining one (*L. acanthia*) appears to be peculiar to the Bermudas.

shore), an individual which was at once seen to be peculiar. The Holothurian was about 25 cm. in length, and of a deep yellowish-brown colour, unmarked by spots of any other hue. Anal teeth were particularly prominent, and the pediciles and ventral surface were tinged with greenish pigment, such as one is accustomed to see in *Holothuria captiva* and in *H. surinamensis* (Crozier, 1915, p. 274). *Stichopus* has no anal teeth, and totally lacks this green pigment. The specimen was unfortunately lost before detailed examination could be given it. Attempts to discover an additional example have thus far been fruitless.

The single specimen observed has, however, considerable zoö-geographical interest. It seems probable, from the external characters above mentioned, that it is an *Actinopyga*, presumably *A. agassizii* (Selenka) *, which is known from the Bahamas, Florida, Tortugas, Barbadoes, Jamaica, and Hayti (Sluiter, 1910). The inference seems fair that it represents a recent arrival in Bermudan waters, since previous extensive and detailed collecting has failed to reveal its presence, and since only a single specimen has been found. Concerning the method whereby, on this assumption, it came to Bermuda, one can only speculate. It may have been transported either (as a larva) by ocean currents or (as an adult) upon the bottom of a vessel. The latter seems the less probable.

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* I am indebted to Dr. H. L. Clark for a suggestion regarding the probable identity of the specimen.

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With One Plate.

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W. J. Crozier.

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Among early naturalists it was quite commonly held that in many cases the coloration of marine invertebrates, such as turbellaria, was directly determined by that of the pigmented substratum upon which they fed. In this way it was attempted to account for certain conspicuous resemblances between the color of species living in company with sponges, ascidians, and the like, and that of the organisms over which they crawled. Furthermore, these color agreements have frequently been considered valuable to the species concerned, according to the scheme advocated by the general theory of protective coloration (cf. Potts, 1915). Increasing knowledge of animal pigments has, however, served to develop a well-founded distrust of so simple an explanation for correspondencies in the pigmentation of associated forms. Several instances have recently come to my notice which seem of interest in connection with the idea of the origin of color in certain invertebrates from the pigmentation of their food. In the one notable case of color agreements which has been adequately studied (the prawn Hippolyte), this view has been decisively rejected (Gamble and Keeble, 1900; Gamble, 1910).

The present observations concern a polyclad turbellarian, Pseudoceros sp., found in association with various tunicates, upon the surface of which it has been seen to feed. This flatworm, of which the general characteristics may be gathered from the figures, apparently belongs to the genus Pseudoceros; but it does not agree with the diagnoses of any of the four species of this genus which Verrill (1900, 1901) has described from Bermuda.[1] I must refrain from attaching a name to it until its anatomy shall have been studied.

This form seems not to be common at any time of year. Although

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[1] Several of Verrill's species were founded, apparently, on color differences of single specimens.

a somewhat careful search for it has been made on the basis of its habits, as revealed by such individuals as have been found, only a small number have been seen. It has therefore been impossible to collect a quantity of the animals for purposes of experimentation, and these notes are, in fact, based upon observations made with only six specimens.

The first individual of this type obtained was found in the branchial sac of a colorless, transparent ascidian, Ascidia curvata Traustedt, which was, as is usually the case with A. curvata, attached to the under side of a flat stone. The polyclad was of fair size, 17 mm. in length when creeping undisturbed. It was observed frequently to come out of the ascidian, and to creep about the aquarium in which the animals were kept. It was marked as shown in Figure 7, but its body, aside from the black cross-bars, was entirely devoid of coloring matter, its substance being of a velvety opaque white appearance.

Three other specimens were taken among separate colonies of the orange colored Ectinascidia turbinata Herd.[2] growing on the reefs. These colonies of the tunicate were affixed to the dead upper portions of gorgonian "whips." In one instance the colony was closely united with a mass of Rhodozona picta (Verr.), the test of which is gelatinous, transparent, and colorless.[3] The polyclads obtained from the Ectinascidia colonies are well depicted in Figure 2. It will be noted that there is a very fair agreement between the general hue of such an individual and that of the test of its host (Fig. 1).

The remaining two examples were obtained from the dark purple-black Ascidia atra Les. The one illustrated in Figure 7 came from the interior of a dead test of this species, the other, of a much darker cast, being found in the branchial sac of a healthy individual.

There is an obvious, striking parallel between the coloration of these animals and that of the tunicates with which they were individually associated. That there is any protective (concealing) value behind this, can, I think, be confidently denied. For, as a matter of fact, the flatworms when in exposed positions are perfectly conspicuous in spite of the agreeing element in their coloration. This was notably the case with the specimen found in the branchial chamber of the transparent A. curvata.

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[2] There is some reason to believe that this species is different from that recorded under this title by Van Name (1902).

[3] It is a curious fact that in the instances of compound colonies, which are not infrequent, the Ectinascidia is practically always the upper, the Rhodozona the lower, member of the group.

It is of more value to discover the source of the pigmentation than to speculate concerning its "function." A simple experiment showed that, as was to be expected from what is known of some other turbellarians,[4] a good fraction of the color seen in such specimens as those drawn in Figures 2 and 7 was due directly to food in the alimentary spaces.

The individual shown in Figures 2 and 3 was isolated from its Ectinascidia colony (cf. Fig. 1) on July 10, 1916. Five hours later it had become considerably paler (Fig. 4); and two days later it was very conspicuously so, as indicated in Figures 5 and 6. It was then returned to a small dish containing several Ectinascidia zoöids, one of which the flatworm very promptly found and began to feed upon, creeping over its surface. After six hours it had assumed a brilliant orange color, like that of Figure 2. The major portion of the orange pigment comes, then, directly from the excreted pigment-bearing cells at the surface of the tunicate test. A similar experiment was made, with a corresponding result, in the case of one of the purplish-black flatworms found with A. atra.[5]

There appears, however, to be a minimum below which the pigmentation cannot be reduced by moderate starvation. After four days in seawater, removed from their host, two of the orange specimens were still in the condition depicted by Figure 5. So far as could be made out from microscopic examination under gentle compression, no orange pigment was retained in the digestive system, although some was present in the integument.

The readiness with which these polyclads return to their own particular kind of tunicate is surprising. With all of the individuals obtained, tests were made by giving them the opportunity of feeding upon E. tubinata or A. atra, placed together in the aquarium, and in two cases specimens found on E. turbinata were also offered individuals of A. curvata. When kept in aquaria the polyclads frequently left their host and wandered about the dish, but in all these instances, as well as in numerous trials in which they were artificially removed, they always returned to that type of ascidian upon which they were originally found. Nor could they be induced to feed upon a different species. I tried in this way to alter the coloration of the specimen found in A. curvata, and of two of those taken on Ectinascidia, namely by plac-

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[4] It should be stated, though, that practically no observations have been recorded respecting the food of the brilliantly colored polyclads.

[5] For a note on this pigment, see Crozier (1916).

ing them upon A. atra in small aquaria containing no other tunicates. But they would not remain on this ascidian, they would not feed, and indeed died in the course of two days.

There consequently seems to be a close correlation between the habits of the three color varieties — for I believe the evidence warrants the view that they are "physiological varieties" of one species — and their ability, on the one hand, to feed on the particular ascidian which harbors them and, on the other, to "make use" of the pigments involved. This correlation is also suggested by the size of the three varieties, which, so far as I have been able to observe, increases directly with that of their tunicate hosts (E. turbinata, A. curvata, A. atra), the average lengths of the respectively associated polyclads being 6, 17, and 20 mm.

Agar's Island, Bermuda.

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EXPLANATION OF PLATE.

FIGURE 1. A group of zoöids from a colony of Ectinascidia turbinata (× 1).

FIGURES 2 & 3. Pseudoceros found on E. turbinata, freshly removed (× 5).

FIGURE 4. The same individual as that shown in figures 2 and 3, five hours after removal from its host (× 5).

FIGURES 5 & 6. The same individual, two days after removal from its host; Fig. 6 is a ventral view (× 5).

FIGURE 7. Pseudoceros found inside the tunic of a dead Ascidia atra (× 2).

The figures are by Miss H. E. Fernald.


1


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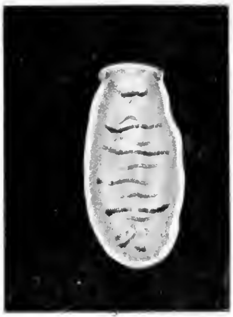
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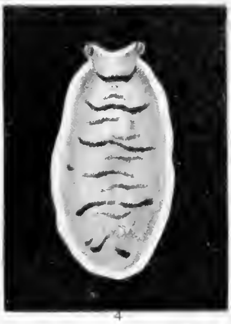
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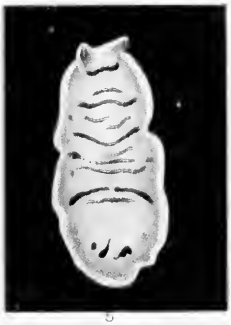
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THE INTRODUCTION OF WEST INDIAN ANURA INTO BERMUDA.

By P. H. Pope.

With Two Plates.

From the Bulletin of the Museum of Comparative Zoölogy
at Harvard College, Vol. LXI, No. 6.

CAMBRIDGE, MASS., U. S. A.
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No. 6.— *The Introduction of West Indian Anura into Bermuda.*

CONTRIBUTIONS FROM THE ZOÖLOGICAL LABORATORY OF THE MUSEUM OF COMPARATIVE ZOÖLOGY AT HARVARD COLLEGE, No. 294.
CONTRIBUTIONS FROM THE BERMUDA BIOLOGICAL STATION FOR RESEARCH, No. 63.

BY P. H. POPE.

BOTH the situation and the physical characteristics of the Bermuda Islands appear to be unfavorable for supporting amphibian life. The situation, over 600 miles from the nearest land, has effectually prevented any natural migration from North America or the West Indies. Consequently there are no amphibians native to the place. The physical character of the country seems to be fully as unfavorable as its location. The porous limestone rock of which the islands are composed allows the water to soak away through it, so that there are no streams or springs, and even stagnant pools of fresh water are rare. Since we think of amphibians as animals that pass through a tadpole stage in water, this shortage of fresh water would seem to be quite enough to prevent the increase of any amphibians that might be introduced.

These conditions would probably prevent the spread of any North American frog or toad, but there are three species which have been brought in from South America and the West Indies, where they are adapted to tropical conditions and consequently fitted to thrive in Bermuda.

The observations on which this paper is based were made during two seasons spent at the Bermuda Biological Station for Research in the summers of 1915 and 1916. I was in Bermuda from about the middle of June to the first of August both years and, incidentally to other work, had the opportunity to study and photograph the species here described.

A grant from the Humboldt Fund of the Museum of Comparative Zoölogy, made this possible. I owe thanks to Dr. E. L. Mark, the Director of the Station, and Dr. W. J. Crozier, the Resident Naturalist, for many courtesies extended to me during my stay and for valuable information and advice. Also to Mr. J. M. Godet of Paget and Mr. N. E. Lusher of 'Grasmere' for specimens and information.

BUFO AGUA DAUDIN.

The Great Surinam Toad, *Bufo agua,* was the first of these species to be introduced. F. C. Waite (:01), writing in Science, gives a brief account of its importation.

"The history of its introduction, as gained from an interview with Captain Vesey in July, 1900, is as follows: Captain Nathaniel Vesey (at present a member of the Colonial Parliament from the parish of Devonshire) 'about fifteen years ago' engaged the master of a vessel plying between Hamilton and Demerara, British Guiana, to secure for him some of the Guianan toads, with a view to using them to catch garden insects. The toads were brought from Demerara to Hamilton, and were carried out to Devonshire by a native, who must have purloined some of the animals, for individuals were seen near the native's home (Tuckerstown), ten miles distant, soon afterward. Captain Vesey liberated 'about two dozen' individuals in his garden, where they thrived from the first and ate many insects."

Dr. Crozier has recently given me further data regarding the spread and increase of the toad,

"F. Goodwin Gosling, Esq., Hon. Secretary of the Bermuda Natural History Society, who has had opportunity to observe Bufo agua in Bermuda since the time of its introduction there, informs me that after several years subsequent to the first appearance of the toads they had increased greatly in numbers, and that individuals of large size were quite common. So numerous were they that in the spring the roads near their spawning places were not infrequently made literally black by hordes of the animals. They became, in fact, something of a public nuisance, through so many of them being killed by carriages upon the roads. But in later years it has been very noticeable that the number of the toads has greatly decreased, and that very large specimens are by no means abundant. Moreover, the largest size now seen does not appear to be anything approaching that of the huge Bufos which were common twenty years ago." — *W. J. C.*

Because of the facts mentioned above, and also because of its habit of getting into water tanks, the big toad was not welcomed at first, and was called Captain Vesey's nuisance. Later it became known that its principal food was cockroaches, and today it is thoroughly appreciated and protected by public sentiment.

In late June and in July I found these toads abundant about roadsides, gardens and edges of mangrove swamps in Pembroke Parish. They are nocturnal in habit, like our American toad (*Bufo americanus*). A street light half way between 'Grasmere' and Hamilton was a favorite place for them, and two or three were usually to be seen under it, picking up the insects that were attracted by the light. If alarmed they travel by a series of rapid hops, giving the effect of a run and going much faster than a person can walk. In the day time they hide under stones or boards, or burrow into soft earth. I have sometimes seen them in little burrows in the side of a bank, where they had dug themselves in just far enough to be out of the sun.

Bufo agua is the largest of living toads. An average female measured 145 mm. from snout to vent, and Waite describes one 155 mm. in length.

The sexes are quite differently marked, as the accompanying photographs show. In general appearance the female resembles our American toad, but there are certain marked differences. The body is flatter and longer in proportion to its bulk and the arms are longer, so that the whole appearance of the toad is less fat and clumsy. The parotoid gland behind the ear is very large, about 38 mm. long and 25 mm. wide, and closely set with pores. These are the openings of glands that secrete a poisonous milky substance, which is exuded when the toad is injured. The bony cranial crests in front of these are very conspicuous, forming a system of dark-colored ridges above the ear and eye, those of the two sides joining in a rather obtuse angle above the snout.

The color of the female is dark brownish gray with a suggestion of olive, while the head parts and dorsal stripe are light yellowish brown. There is a pair of large dark spots on each side of the dorsal stripe. The skin of the back is rough and warty and the warts are usually darker colored than the rest of the back.

The male is smaller, usually about 13 mm. shorter, and more active than the female.

The coloring of the male is pale yellowish brown with only faint traces of the markings seen in the female. The warts are rather smaller and are covered with black tubercles.

The call of the male is a deep, booming trill suggesting that of our American toad but louder and more resonant.

In regard to the poison of this toad, Verrill (:02) says:

"This toad is believed. . . .to have a very poisonous secretion from its parotid and dorsal glands. It is said that dogs that mouth them invariably die within a few hours. The secretion of the glands, when injected into the circulation of dogs, birds, and other animals, causes convulsions and death, even when in small doses. Mr. A. H. Verrill, of my party, on one occasion saw the venom ejected as a fine spray, from the parotid glands of a large toad, when it was much irritated."

For a good account of the histology of these poison glands, and a fairly full bibliography on the subject, see Shipley and Wislocki (:15).

The eggs are laid in water in the spring. Standing fresh water is scarce in Bermuda, but there are places where pools exist in rainy weather. This water is not always fresh, but brackish water is not refused, and it is said that toads will sometimes lay their eggs in the salt water of mangrove swamps.

The development of an amphibian in salt water seems very unusual, but Glaser (:12) discusses a case of development of frog larvae, described by Pearse (:11), in the mouth of a creek emptying into Manila Bay where the water was partly salt. To account for this Glaser experimented on the larvae of *Rana pipiens* and draws the following conclusions:

"The ability of amphibian eggs to develop in sea water is dependent on the principle of ionic antagonism. In addition to this, however, their power of acclimatization plays an important rôle, for it not only enables them to withstand the passage from dilute to strong solutions, but the opposite process as well.....If in addition to this we remember that the species found by Pearse is probably racially acclimated to the conditions under which it lives, his findings do not appear inexplicable."

The breeding season of *Bufo agua* depends largely upon atmospheric conditions. If there is plenty of rain it may begin in February, but if there is continued drouth it may be delayed until July. April is about the usual time.

Clark (:16) and Ruthven (:16) have collected data that show the variability of the breeding season.

Clark quotes a letter from Barbados as saying:

"It certainly lays its eggs at least twice a year. In August last year (1914) ponds in Barbados were full of tadpoles, and again in February this year (1915) the same thing was noticed."

In Trinidad the breeding season is reported as August–October. In Demerara "it appears to breed about the commencement of the wet season, somewhere in November or thereabouts."

Ruthven has made some observations on the habits of the species in Demerara:

"On the Demerara River, about thirty-five miles south of George-town, in 1914, tadpoles were abundant in July and August, and a lot taken during the last week in July reached the adult stage on and after August 16. From this the writer concludes that the eggs were laid about the first of July, and that in Demerara the species breeds in the long wet season, from the middle of April to September first. It is possible that it also breeds in the short wet season, which begins in November and lasts until the end of January, as stated by Bodkin (quoted by Clark), but, in the opinion of the writer, this has not as yet been established."

An interesting question arises here as to whether the toad breeds once or twice a year.

In Bermuda it probably spawns but once, as there are no definite data to the contrary. However, this may be due to the fact that the winter season is much cooler than summer, and probably the toads are less active at that time.

Dr. Crozier has looked for them this winter (1916–1917), but failed to find any, so they are probably in hibernation.

From Ruthven's paper it appears that development from egg to adult requires about forty-five days. Probably this would be shortened by the drying of the pools, as is the case with our northern amphibians. From what I have been told, I think that development must be even more rapid than this in Bermuda. It would be interesting to obtain exact figures on this question, for such a short tadpole stage is unusual.

Dr. Mark has given me the following data:

"In the spring of 1903, in company with Professor C. L. Bristol of New York University, I made a trip to Bermuda. In the course of one of our excursions made at the invitation of the Hon. Ambrose Gosling, the Hon. F. Goodwin Gosling and the late Mr. James Trimingham, we visited 'Spanish Rock' near mid-day April 22. Before reaching the Rock we found, on the slope facing away from the ocean and toward Spittal Pond, a small pool of rain water (there had been a heavy shower the night before), and in this pool there were large numbers of the huge toad — *Bufo agua* — in pairs. The females were engaged in spawning, and the numerous strings of spawn were stretched across the pool in almost every conceivable direction. The pool, some fifteen or twenty feet in diameter and only a few inches deep, was of so temporary a character that its bottom consisted throughout of turf, not unlike that immediately surrounding it which was not submerged. I secured a considerable quantity of the most freshly deposited 'strings' and kept it in a vessel with some of the rain water. Portions of this material I preserved in formalin at intervals, and from time to time made the following notes on the condition of the spawn, which was brought to Cambridge, where I arrived on the 26th of April:

'Eggs laid at about 12 o'clock (noon) April 22, 1903. About 60% to 70% proved to be fertilized.

April 23. Infertile eggs grayish in color. Some of them may have been injured in transportation.

April 24, 4.15 P. M. Egg envelopes becoming attentuated, not so stiffly gelatinous. Strings tending to float (due to decomposition of infertile eggs?).

April 25, 8.00 A. M. All embryos have pierced their envelope and are clinging to it by the head, on the outside (of the envelope). Infertile eggs still remain in their envelopes.

9.30 A. M. First perceptible movements, slight quivering; embryos still adhering by head to remains of envelope.

April 26, 8.30 A. M. Much more active; those where envelope entirely consumed moving about with motion of larvae of mosquito. Some clinging to leaves.

9.30 A. M. All freely swimming.

April 27, 8.00 A. M. All swimming or clinging to sides of aquarium.'

E. L. MARK."

In addition to this, Plate **2**, fig. 7, 6 show eggs and young tadpoles which were collected by L. J. Cole in July of the same year (1903). The eggs closely resemble those of *B. americanus* both in size and appearance. Shrinkage of the eggs in the formalin in which they are preserved makes it almost impossible to identify the exact stages of development, but it is plain that none of the eggs were past the early cleavage stages. The tadpoles are black in color and resemble those of *B. americanus*. They measure from 8.5 to 10.9 mm. in length. They have the typical early tadpole form. The buds of the hind limbs are present, but hardly visible to the naked eye.

This material was dated July 27 and July 31, 1903. The following note shows where it came from:

"B. B. S. Station 1406, July 26, 1903.

A small fresh-water pond to the west of the Middle Road just south of 'Green Hill.' Pond only 20–30 feet from the roadside (Lat. 17′ 58″ Long. 44′ 52″). Pond is about 20 feet long and 8 feet wide. At present contains about 1½ Ft. water from heavy rain early in the morning (3 A. M.) of July 25th. The water of the Pond is green with some microscopic alga. Bufo marinus breeding in large numbers.

L. J. COLE."

The place spoken of is located near the southeast margin of Devonshire Marsh. It is perhaps three miles from "Spanish Rock," where the other eggs were found April 22nd of the same year. I am somewhat at a loss to explain why one group of animals should spawn in April and another group only a few miles away should wait till July. I do not think that the same toads were spawning twice in the same year, for the dates are only three months apart.

Metcalf (: 14) has described a new species of Opalina found in the rectum of some specimens of *Bufo agua* collected in Jamaica. Since the Bermuda toad came from Demerara, it would be interesting to see whether it, too, is infested by the same parasites.

ELEUTHERODACTYLUS JOHNSTONEI BARBOUR.[1]

The "whistling frog," *Eleutherodactylus johnstonei*, was introduced accidentally. I have been told that it was brought in at Admiralty House, Spanish Point, about 1886, probably coming from Jamaica, since palms and ferns are often brought from there to Bermuda, and that it spread slowly at first, but much more rapidly during the last ten years.

In a recent letter Dr. Crozier says:

"The 'whistling frogs' were here before 1880 in very small numbers. In that year Lady Bedford, wife of Admiral Bedford, brought to Admiralty House from Jamaica a pair which were liberated. (So says Mrs. Abbott, editor of the Gazette)."

These data appear to be correct for the most part. It is highly improbable, however, that the animal came from Jamaica, for it has been reported only from Barbados, where it is supposed to be native, and from Grenada, where the type specimens were taken. Since both these islands are, like Bermuda, British possessions, it is not unlikely that it came from one or the other of them instead of Jamaica.

Its range in Bermuda now extends from the Causeway, on the north, to Paget on the south. The animal is surely abundant enough south of Castle Harbor, and this summer I heard a single one in the town of St. Georges, showing that they have crossed the Causeway. Southward they have reached Paget but have not spread beyond there.

The creature itself is a tree frog with well developed adhesive discs on its fingers and toes. It is not a Hyla, like our North American

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[1] For description and figures of this species see Barbour, 1914.

tree frogs, but belongs to a nearly related family, the Polypedatidae. The differences between the two families are in the structure of the skeleton and will not be discussed here.

The "whistling frog" (Plate **1**, fig. 2; Plate **2**, fig. 5), as Bermuda people call it, is very small. A large female measured 28 mm. long, while the average male is about 22 mm. in length.

In color they are grayish brown above with darker transverse bands in front of the eyes, between the shoulders, and above the sacral humps. The distinctness of these markings depends upon the phase of the animal's coloration. In the day time the color is usually very dark and the markings hardly show, but at night it becomes pale and then they are quite conspicuous. The hind legs are barred with dark. The under parts are pale and not spotted. The skin is comparatively smooth except underneath, where it is granular.

A striking peculiarity of this group, which especially fits it for life in Bermuda, is the fact that in development the entire larval stage is passed in the egg, a free-swimming tadpole stage being unknown. The eggs are laid either on plants or under stones on damp ground and the young hatch out in the form of perfect frogs, quite able to take care of themselves.

Until lately nothing was known about the breeding habits of this species. In July I found females full of large eggs and concluded that the breeding season was in the fall. This has been confirmed by a recent letter from Dr. Crozier in which he says:

"Sept. 15, 1916. In Paget I found some eggs which I took to be those of E. johnstonei. They were fastened to twigs, ... about a dozen in a cluster, all 'round the stem. Eggs 1–1.5 mm. in diameter."

In June and July I found "whistling frogs" very abundant all through Pembroke. They occur almost everywhere, especially, however, in thickets of oleander and cedar, and most abundantly in swampy places and in growths of Bryophyllum or "life plant." The old quarry at Pembroke Crossroads, shown in Plate **2**, fig. 8, was my favorite hunting ground. I took about 50 from the place last year and fully as many this year, but the number did not seem to be diminished thereby.

I found it easy to catch them at night by following up their call with a light. They usually sit on a sloping leaf or rock, always with the head downward and the hind legs half spread. The male has a large, collapsible throat pouch, wanting in the female, which opens from the floor of the mouth by a pair of slits, one on each side of the tongue. When the call is given this pouch is expanded like a great bubble until it is larger than the head. Then the air is taken back into the lungs again, expanding the body in turn, while the throat pouch nearly disappears. The flash-light picture (Plate 2, fig. 5) shows a male sitting on a rusty tin box and singing. The call had just been given, the throat pouch was collapsed and the body inflated when the flash went off.

The call is a thin, high-pitched whistle, somewhat like that of the Spring peeper, *Hyla pickeringii*, though rather more bird-like than that. Some notes are trilled a little, but the general effect is much like the spring chorus that we hear in the swamps. Unlike that, however, this chorus is not a temporary thing during the breeding season, for it continues all summer, apparently as long as the animal is active. Residents say that the chorus begins in April and ceases late in October or early in November, when the animal becomes dormant.

This story of the hibernation of the frog may or may not be true. The call ceases, but whether the frog is still active I do not know. It may really be hibernating or merely silent during the winter. Since most of the people have never seen one, they have no way of knowing except by the call.

Dr. Crozier tells me that his observations in 1915 agree with the popular idea, but in the winter of 1916–1917 they continued calling in small numbers most of the winter. His latest word on the subject follows:

"Mar. 16, 1917. I have not heard a 'whistling frog' now for about three weeks, perhaps a little more."

"April 15, 1917. Search for nests of E. johnstonei resulted in discovering several quite 'sleepy' nests of them on April 10th, and on April 14th I found under my front door step, buried in moist earth, a closely packed batch of more than a dozen. They 'came to life' very quickly, and in two minutes were jumping all over the place. A number were secured. The woods are full of them, singing as I write — as least it sounds so."

It is their abundance and their persistent singing that makes Bermuda people consider the "whistling frogs" such a nuisance. The call is not disagreeable in itself, but I can readily see how anyone could get very tired of hearing it all summer long from the shrubbery under his window. When I was collecting them beside the road the usual comment of the passerby was: "I wish you'd catch them all."

In spite of its long continuation, the call may be the mating song of the male, for I have seen behavior that may have been equivalent to a courtship. On July 6, 1916, I saw three pairs acting in the following way. The male was singing loudly and the female was sitting near by, watching him from a distance of one to six inches.

The "whistling frog" is nocturnal in habit. I have heard its call as early as half past five in the evening and as late as seven o'clock on a wet morning, but never a sound through the heat of the day, the day time being spent in hiding, usually under stones or in stone walls or rubbish.

The exception to this rule is seen in the following note by Dr. Crozier:

"On October 31st, 1916, I noticed that the 'whistling frogs' were singing loudly at 1 P. M. It had begun to rain rather heavily, and the sky was much overcast. During the next succeeding three days, the rain continuing all the while, the tree frogs kept up a steady chorus throughout the whole of each afternoon. They did not sing in the morning (9–12 A. M.), but it is quite clear that under proper conditions of moisture and absence of strong light, the singing of these frogs is not restricted to the night hours. It may be significant that this time of year appears to be that of egg deposition."

Females are rarely seen at night. It is the males alone that sing and thus make themselves conspicuous. I have caught several by turning over stones in the quarry, where they were abundant at night. But even in the day time the males seemed about twice as common as the females.

The food is interesting as showing what economic value is to be attached to this ubiquitous noise-maker. An examination of fifty-eight stomachs showed that the "whistling frog" is not at all particular what it eats. Almost anything alive that is not too large to swallow appears to be satisfactory. A partial list of the material found in the fifty-eight stomachs follows:

Aphids	60	specimens
Insect larvae	36	"
Ants	29	"
Various Diptera	24	"
Spiders	22	"
"Pill bugs" (Isopods)	14	"
Centipedes	9	"
Young of *E. johnstonei*	1	"

On the whole the list is decidedly favorable for the case of the frog, and we must conclude that it is not the unmitigated nuisance that Bermuda people consider it.

ELEUTHERODACTYLUS LUTEOLUS GOSSE.

In June, 1916, Mr. J. M. Godet sent to the Station several specimens of an Eleutherodactylus new to Bermuda. These frogs had been caught and brought in alive by Mr. Godet's cat. The cat certainly qualified as a good collector, for in the course of the summer he brought in about twenty-five specimens. Later in the season Mr. Godet was having a stone wall near his residence removed and his workmen came across many of these little frogs hiding under stones.

The new frog (Plate 1, fig. 1), which Dr. Thomas Barbour has kindly identified for me as *Eleutherodactylus luteolus*, hitherto found only in Jamaica, appears to be a little larger than *E. johnstonei*, yet the average female measures only 28 mm. The difference is in girth of body rather than in length, for it is not quite so slender. Besides this, the males are larger in proportion and do not seem to outnumber the females as much as in *E. johnstonei*. In color the creature is pale gray, changeable to dark gray. The under parts are paler and the skin there is granular. Indistinct barring shows on arms and legs. There is a dark streak, edged anteriorly with white, between the eyes and rather faint dark markings on the back. These are situated between the armpits and at the sacral hump, corresponding to the more distinct markings seen in *E. johnstonei*. A black line extends from snout to eye, and the ventral two thirds of the iris is dark. Behind the eye the line continues along the side and is edged ventrally with black blotches to a point just back of the armpit. In about half the specimens that I handled there was a distinct, light vertebral line running back from the snout to the vent, where it bifurcates and extends along the posterior side of the thighs.

Nothing definite is known about the introduction of this species. Mr. Godet tells me that its peculiar call has been heard in Paget for at least ten years. It seems to be most abundant near his home in Paget about opposite Isle of White, but it does not occur west of Paget. I have heard a few, and collected one, at Pembroke Crossroads but have not heard them further east.

The call is very hard to describe. It is a soft, chuckling note, almost a trill. It is not very loud and seems to require little effort. The throat pouch is slightly expanded, but the body does not become inflated as in *E. johnstonei*.

In going from Hamilton to Paget one evening I heard both *E. luteolus* and *E. johnstonei* near the city, but as I went further out the latter became less abundant and the former more so, until, in the region opposite the Isle of White, the shrill pipe of *E. johnstonei* was not to be heard, while the softer note of *E. luteolus* filled the air, suggesting a chorus of toads in the distance.

Whether this region marks the present western limit of the range of *E. johnstonei*, and, in case it does, whether *E. luteolus* tends to crowd it out in the struggle for existence, are interesting questions still to be settled.

Another question in regard to distribution comes up in this connection. In the case of the toad, we have seen that it became very abundant soon after it was introduced but that now its numbers have decreased until it is little more common than the American toad in New England. Both species of Eleutherodactylus are spreading in Bermuda and both are extremely abundant within their present range. It remains to be seen whether they will decrease in numbers, as the toad has done, when they have spread over the whole extent of the islands.

The females of *E. luteolus* contained large eggs in July. Barbour (: 10) says:

"The development of this frog is of interest. The eggs, from thirty to thirty-five in number, are laid in depressions in damp ground under stones or logs. Mr. Wight has also found these nests and writes:

'Port Antonio, Jamaica, Nov. 30. Thirty-three eggs in slight depression, damp ground. Eggs scarcely adherent. Movements of embryos visible. 168 hours later two frogs hatched. After 312 hours the whole lot had taken on the light brown color which is typical of many adults.'"

Dr. Crozier, in the letter of Sept. 15, previously mentioned, confirms this observation:

"Also eggs, which I take to be those of the other, larger form (which on dissection now seems 'ripe'), were found among stones in an old stone wall. *These* eggs were laid in a cluster of about 30, closely adhering to one another upon damp, firm earth; the eggs in this case were 3 mm. in diameter, the jelly being somewhat swollen."

In another letter dated Feb. 1, 1917, he says of its winter habits:

"The E. luteolus does not hibernate, at least not invariably. Mr. Godet's invaluable cat is still catching them in small numbers."

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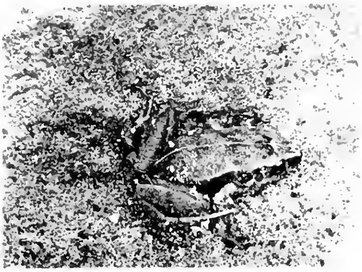
PLATE 1.

PLATE 1.

Fig. 1. Eleutherodactylus luteolus Gosse. × 1.
Fig. 2. Eleutherodactylus johnstonei Barbour. Female. × 1.
Fig. 3. Bufo agua Daudin. Female. × $\frac{1}{2}$.
Fig. 4. Bufo agua Daudin. Male. × $\frac{1}{2}$.



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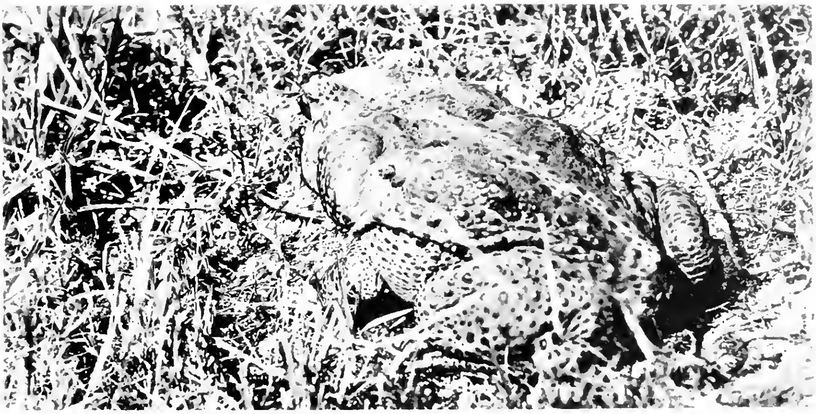

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PLATE 2.

PLATE 2.

Fig. 5. Eleutherodactylus johnstonei Barbour. Male singing. × 1.
Fig. 6. Bufo agua Daudin. Young tadpoles. × 1.
Fig. 7. Bufo agua Daudin. Eggs. × 1.
Fig. 8. Abandoned quarry at Pembroke Crossroads, showing in the foreground growth of Bryophyllum.

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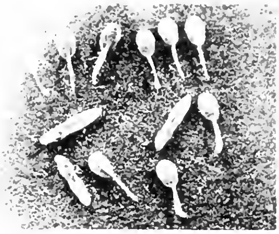

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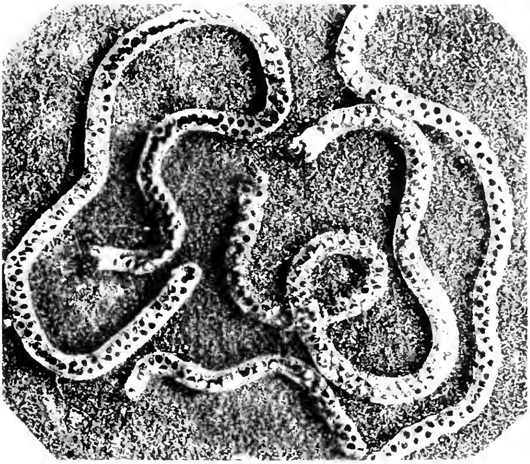

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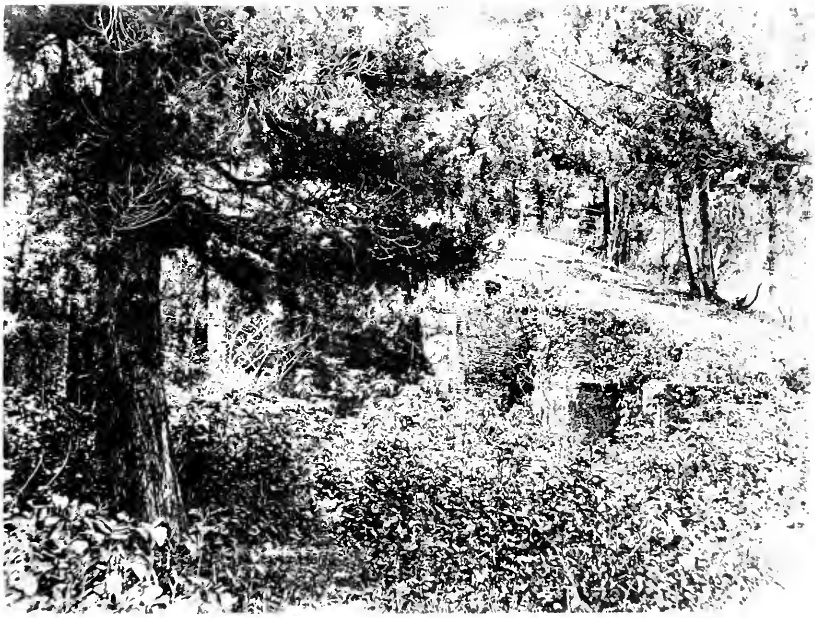

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FOR RESEARCH.

No. 64.

SOME STRUCTURAL VARIATIONS OF CHROMODORIS ZEBRA.

No. 65

A METHOD OF PRESERVING LARGE NUDIBRANCHS.

BY W. J. CROZIER.

FROM THE NAUTILUS, VOL. XXX, NO. 12.

CAMBRIDGE, MASS., U. S. A.
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SOME STRUCTURAL VARIATIONS IN CHROMODORIS ZEBRA.

W. J. CROZIER.

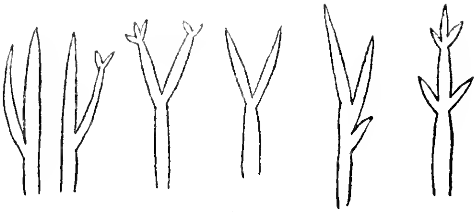
Contributions from the Bermuda Biological Station for Research, No. 64.

Abnormalities of a minor character are by no means uncommon in nudibranchs, and, while these features are usually not of any great morphological significance, some of them seem sufficiently curious to warrant description. I have noted several such deviations from the typical structure while examining a large number of specimens of *Chromodoris zebra* Heilprin.

Smallwood (1910) has described some of the variations in the coloration of this animal, and has also referred to the variability shown by the branchiæ, particularly in the manner in which one or several of these organs terminate by division of their free ends into several parts. I have elsewhere (Crozier, 1917) made note of the variation in the number of the glandular papillae which occur upon the ventral surface of the posterior border of the mantle.

Variation in the branchiæ is, in fact, somewhat more frequent and more extensive than Smallwood observed. Not unusually, branchiæ are to be seen which not only divide to a greater or less extent at their tips, but also show a branching at some distance from the tip (Fig. 1). In many instances the presence of an accessory branchia arising in this way is unaccompanied by duplication of the pointed tips.

The high sheath which surrounds the branchial rosette is normally quite smooth. In only one of the many hundreds of *Chromodoris* which I have handled was there noted any other condition. In this single specimen, however, there were three distinct ridges running from the dorsal surface to the external margin of the branchial collar; two of these ridges were extended in an anterior direction, their edges being sharp and



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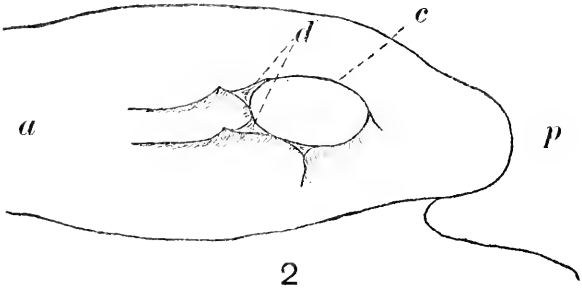

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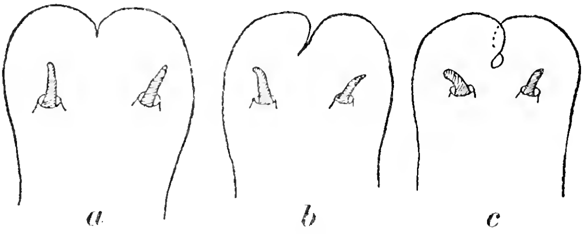

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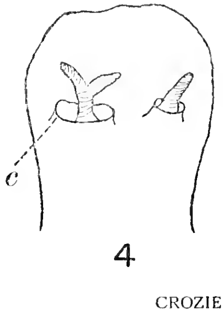

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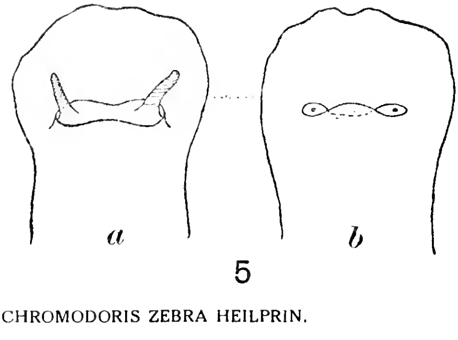

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CROZIER: CHROMODORIS ZEBRA HEILPRIN.

prominent, while the third, less conspicuously developed than the other two, was on the left side of the collar. The appearance of these structures is shown in Figure 2, where may be seen the manner in which the ridges were united with the collar.

The edge of the mantle occasionally shows evidence of injury, and this may explain the origin of modifications found at the anterior end of the mantle in several specimens. These modifications consisted in a well-defined median indentation of the buccal veil, which was thus symmetrically bilobed. But this region of the mantle is almost always folded at the margin to some extent, and since the pigment pattern frequently shows no local disturbance at the region of the indentation, the feature which is shown in Figure 3 (particularly at *c*) may be merely an unusually strong expression of a tendency to wavy folding.

The "rhinophores" of *Chromodoris* (cf. Arey, 1917), which are usually straight, may appear somewhat bent near the tip, or may even assume a slightly corkscrew shape. In one individual there was found a bifurcating "rhinophore" on the left side; the one on the right side was normal. As shown in the accompanying sketch (Fig. 4), the rhinophoral collar (*c*) had grown in such a manner as to accommodate the additional structure.

One specimen occurring among a lot of 231 collected early in January, 1917, was found to possess a striking modification of the rhinophoral collars. Figure 5 depicts the condition referred to, which consists in the fusion of the two pockets, into which the "rhinophores" are respectively retracted, so that but a single depression provided with a single collar is present in this particular animal. The posterior edge of the collar was higher than the anterior one, and when both "rhinophores" were retracted this posterior border of the collar was folded over the anterior edge in such a way as to lead to the appearance of two minute openings into the single pocket.

Agar's Island, Bermuda.

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DESCRIPTION OF FIGURES, Plate VI.

FIG. 1. Branching gills.

FIG. 2. Ridges about the branchial collar; *a*, anterior; *b*, posterior; *c*, branchial collar (gills not shown); *d*, triangular depressions.

FIG. 3. Lobed condition of the buccal veil.

FIG. 4. A bifurcate rhinophore; *c*, collar of rhinophore.

FIG. 5. Fused rhinophoral pockets; *a*, rhinophores extended; *b*, retracted.

A METHOD OF PRESERVING LARGE NUDIBRANCHS.

W. J. CROZIER.

Contributions from the Bermuda Biological Station for Research, No. 65.

Those who have had occasion to study collections of nudibranchs, especially when they include specimens of the larger tropical species, have doubtless often wished that the organisms submitted for their examination had been so preserved as to exhibit in more natural fashion the appearance of these creatures when alive. After various attempts to secure good preparations, I find that the simple procedure herein outlined gives tolerably fair results. The method has been tried almost exclusively upon *Chromodoris zebra*, but it seems likely that other large forms will yield equally good preservations when treated in the same way.

A saturated solution of cocaine hydrochloride is made up in sea water, and 2–3 cc. of this solution is then injected into the heart (or into the region of the heart) of *Chromodoris* by means of a syringe and hollow needle. A "Record" syringe, such as is used by surgeons, is useful for this purpose. Within an hour or so—depending on the temperature, on the size of the animal, and on the exact amount of the narcotic that has been injected—the nudibranch will be fully anaesthetized, usually with the gills and rhinophores fully extended; frequently also the genital papilla will be protruded, and the pharynx everted. It is advantageous to add a few crystals of chloretone to a small volume of sea water containing the nudibranch; furthermore, several injections of the cocaine may sometimes yield a better result than a single dose.

When completely anaesthetized, the animal may be killed and fixed in 75 per cent. alcohol. Precipitated slime, on the surface of the body, can be subsequently removed with a camel's hair brush. In order to avoid the distortion which inevitably results if these large nudibranchs are fixed while they rest upon the bottom of a dish, it is well to suspend them vertically in the fixing fluid until they are killed and begin to harden. This may be done by gripping the caudal extremity of the foot between the jaws of a light "artery clamp" or some similar instrument; or a thread may be sewn through the foot for this purpose.

The injection of a relatively small amount of a narcotic usually gives much better results than does the attempt to anaesthetize these nudibranchs by adding magnesium sulphate, or chloretone, to the seawater containing them. In the latter method, not only does the surface frequently become covered with a number of vesicular blebs, edematous in appearance, but also the proper time for removal to the killing fluid must be selected with considerable care. A similar procedure, involving the injection of chloretone into the body-cavity, has been employed by Pearse[1] with holothurians.

The proper penetration of the fixative is of course important for the conservation of the internal organs. This result may be assured if a fair volume of the fixative is employed, and if in addition an incision several centimeters long is made along the edge of the mantle (preferably on the left side) previous to immersion in the fixative.

Frequently it is desirable that the normal integumentary colors of the nudibranch should be preserved as faithfully as possible. Two fluids which I have found useful with *Chromodoris zebra* are Merkel's fluid and the sublimate-acetic mixture (saturated aqueous solution of sublimate plus 5 per cent glacial acetic acid). The sublimate mixture in particular gives a very fair preservation of the blue pigment of *Chromodoris*, which is permanent for six months at least, if not for a longer period. The sublimate precipitates the blue substance so that it is no longer soluble in aqueous alcohol, and at the same time renders

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[1] Pearse, A. S., 1910. Eine Methode, um Holothurien in ausgedehntem Zustande zu konservieren. Zeits. f. biol. Tech. u. Method., Bd. 2, p. 94-95.

it insensitive to the acetic acid, which otherwise would cause the substance to become pink. Possibly the platinic chloride in Merkel's fluid has a similar action, since I find that both mercurous salts and platinic chloride precipitate the blue pigment from aqueous solutions.

Agar's Island, Bermuda.

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By W. J. Crozier.

From The American Naturalist, Vol. LI, No. 609.

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MULTIPLICATION BY FISSION IN HOLOTHURIANS[1]

DR. W. J. CROZIER

THERE is to be found in various text-books the statement that certain pedate holothurians are capable of spontaneous transverse division, each part so formed producing a new individual (Lang, 1894, p. 1095; Morgan, 1901, p. 144). This opinion seems to be based, so far as I can learn, upon the observations of Dalyell (1851, p. 74; Pl. XIV), although Morgan says that "more recent observers have confirmed this discovery." Chadwick (1891), also, found small individuals of *Cucumaria planci* to undergo self-division, and in one instance the posterior portion so formed also divided. These are records of division in holothurians which were being kept in small aquaria, and there has been no evidence, so far as I am aware, going to show that self-division of adult pedate holothurians is a method of propagation among these animals in their normal surroundings. Hence the possibility of non-sexual reproduction in this way is usually stated with reserve (cf. Lang, 1894).

In other classes of echinoderms (aside from echinoids) the expedient of reproduction by fission is of course not unusual; but in ophiuroids and in such starfishes as *Linckia* (Clark, 1913) and *Coscinasterias* (Crozier, 1914),[2] we are dealing with the division or fragmentation of a

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[1] Contributions from the Bermuda Biological Station for Research, No. 66.

[2] I have been able to secure further evidence regarding the fragmentation of *Coscinasterias* (*Asterias*) *tenuispina* (Lam.), which proves conclusively that the rules previously deduced (Crozier, 1915*a*) regarding this process are indeed valid. This evidence will be published in connection with a description of experiments on the direction of progression in *Coscinasterias*. The presence of great variation in ray-length, as well as of a variable number of madreporites, gives an opportunity to test out in this species the validity of certain ideas concerning "physiological polarization" in asteroids.

many-armed creature relatively deficient in morphological centralization; whereas in *Cucumaria* and in *Holothuria* the body is compactly built, the animal much more of a unified individual. Consequently the self-division of these holothurians is not without interest, especially since in these cases the plane of separation is anatomically perpendicular to that employed among the astroradiates, and it is the purpose of this paper to present evidence which proves that adult specimens of at least one species, *Holothuria surinamensis* Ludw., do as a matter of fact divide transversely into two parts under conditions which must be regarded as normal. Since these divisions are not infrequent in large numbers of specimens, if not in a single life-history, we must conclude that fission represents a regular means of mutliplication in this species.

A few years ago I found (Crozier, 1915*b*) that about 10 per cent. of the examples of *H. surinamensis* which were studied showed a condition of either the oral or of the cloacal end which—on the basis of observed regenerations following experimental cutting—I interpreted as representing regeneration, possibly as a consequence of spontaneous self-division. Similar conditions have been noted by others for some other species of holothurians, *e. g.*, by Benham (1912, p. 136) for *Actinopyga* (*Mülleria*) *parvula* (Selenka), but they have usually been referred to regeneration after injury by such bottom feeding fishes as small sharks. Dr. H. L. Clark informs me that he has found a corresponding state of affairs in some Australasian holothurians, at least in regard to the occurrence in nature of specimens showing posterior regeneration.

I subsequently obtained young individuals of *H. captiva* Ludw., about 6 mm. in length, which were observed to divide spontaneously in the laboratory (Crozier, 1914, p. 18), precisely according to the procedure figured by Dalyell (1851) and by Chadwick (1891). Only a single adult *H. captiva* has been discovered, however, in which there was evidence of normal regeneration; this individual, which was 40 mm. long, was obtained among a group of 47 taken from under a large rock in April, 1916.[3] The anterior end for a distance of 7 mm. from the tip was light greenish yellow, with ten very feebly developed tentacles; there was a sharp line of demarcation between the light yellow surface and the dark olive green of the rest of the body. If *H. captiva* undergoes division normally, it can only occur in very young stages.

With *H. surinamensis,* however, the case is quite different. In Table I there are summarized results of the examination of several series of these animals collected at different times for this particular purpose. It will be noted that in these collections from 2.5 to 16.9 per cent. (on the average about 11 per cent.) of the individuals show a condition of either the oral or of the cloacal end which is interpreted as representing regeneration. This seems to be about the proportion of such instances which is to be met with in general collecting, although numerical records have been kept only in the cases cited. The specimens represented in the tabulation were obtained from one locality, Fairyland Creek, where they notably abound; but the species has been collected at many other stations, where also the regenerating individuals are to be found in approximately the same proportion. The

TABLE I

THE RELATIVE NUMBER OF CASES IN WHICH *Holothuria surinamensis* WAS FOUND TO BE REGENERATING IN NATURE

Date	No. examined	Regenerating			
		Oral	Cloacal	Total	%
June, July, 1913	200	7	13	20	10.0
July 30, 1916	39	0	1	1	2.5
Aug. 26, 1916	84	6	5	11	13.1
Jan. 25, 1917	70	6	3	9	12.8
Jan. 31, 1917	53	4	5	9	16.9
Total	446	23	27	50	11.2

Ratio of regenerating oral to cloacal ends = 1 : 1.17.

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[3] It is known that some holothurians tend to congregate together in considerable numbers at their time of breeding. Graber considered this to indicate the presence of a chemical sense (Delage et Hérouard, 1903).

season of the year seems not to influence the occurrence of regenerating specimens.

The criterion of regeneration in these cases consists in the presence of an anterior or posterior terminal part of the body characteristically different in appearance from the normal buccal or cloacal end, the surface being clearly marked off from that of the rest of the body. In typical examples these regenerated ends of the animal are more sharply pointed than is usual; they bear feebly developed tentacles (at the anterior end), tube feet, and dorsal papillæ, which are less reactive than those on animals judged to be not regenerated; and these appendages are very lightly pigmented (Fig. 1). These characteristics undoubtedly become less prominent with time, the coloration tending, however, to remain pale on the ventral surface (trivium). The first pigment to appear is the green fluorescent one (cf. Crozier, 1914, p. 9 and 1915*b*); the dark brown substance develops more slowly, just as in the growth of the post larval holothurians of this and related species. The spicules of the podia and skin seem fewer than in corresponding non-regenerating parts, but are of the usual sizes and shapes. The tentacles on regenerating buccal ends are always fewer (9–15) than on the normal individual (20).

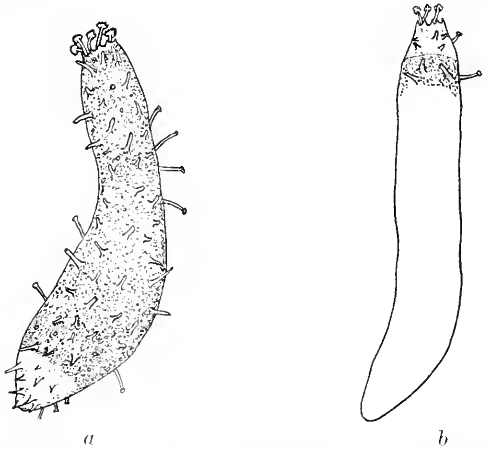

FIG. 1. Regeneration found occurring naturally. Semidiagrammatic sketches, showing differences in pigmentation of *a*, cloacal end, *b*, oral end. Natural size.

That the oral and cloacal terminations just described do in reality represent regeneration, has been verified by observation of the course of regeneration in the laboratory after experimentally cutting the holothurians in various ways (cf. Crozier, 1915*b*). Certain specimens also have been tabulated as "regenerating" when their appearance (Fig. 2, *c*), backed up by dissection, suggested that they had just completed division and had not yet begun to regenerate. These specimens lacked either a cloaca, or the stone ring and buccal structures, depending, obviously, on their former relation to the complete individual from which they were derived.

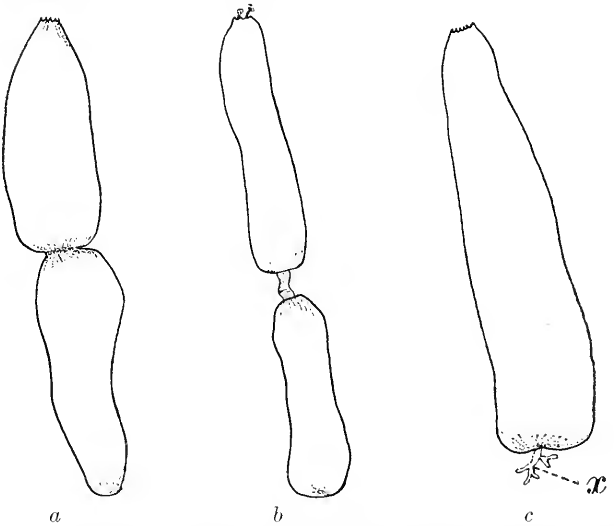

FIG. 2. Outlines of individuals dividing or recently divided. In *a* and *b* the division is shown in progress, × ½; in *b* the exposed portion of the undivided intestine is visible; in *c* is given the outline of a recently separated oral half, natural size. At *x* is seen a protruding bit of the portion of the respiratory trees retained within this half animal. The characteristic puckering of the surface at the division area is also indicated.

The evidence that the regeneration found occurring under natural conditions results from the self-division of adult holothurians, involves two considerations. The first concerns (*a*) the relative size of the regenerating animals, and (*b*) the relative frequency of anterior and posterior ends noted as regenerating. The second has to do with direct observations of self-division.

One hundred *H. surinamensis* collected in Fairyland Creek ranged in length from 6 to 18 cm., with the mode at 14 cm. The regenerating specimens ranged in length from 4 to 9 cm., with the mode at 7 cm. While no numerically exact argument can be based on these figures, since the length of any one holothurian is variable, the fact does stand out that the regenerating animals are about one half the length of the non-regenerating ones. There is also the significant fact that not a single instance has been found in which both a (supposedly) new oral and new cloacal end were present. If self-division has occurred, then we should expect to find new oral and new cloacal extremities in equal frequency; among the rather small number of cases available, we find their ratio to be as 1:1.17, an agreement sufficiently close to favor belief in self-division.

The evidence concerning the second point is even more conclusive. I have seen, in all, nine cases in which a holothurian (*H. surinamensis*), in the laboratory, divided itself into two parts. The animals concerned seemed healthy, and bore no visible signs of having been in any way injured. In no case did the halves so formed redivide, although in two cases the resulting portions lived in the laboratory for a month (Aug. 3 to Sept. 5, 1916), during which time, even in the absence of food, missing structures were regenerated.

In one case the process of division occupied five days; in another, twenty-four hours. Probably it is executed more rapidly in the field. The details of the division were not notably different from those described by Chadwick (1891) for *Cucumaria,* except perhaps in one particular. The intestine is not drawn out between the separated halves, as found in *Cucumaria* and as I have observed in the young of *H. captiva.* Division begins midway of the length of the body with a deep insinking of the "dorsal" bivium. A powerful circular constriction, accompanied by some slight local disintegration of the integument, completes the separation (Fig. 2). During the progress of division the animal is quiescent, although it may be adhering firmly by its tube feet to the vertical wall of the aquarium. When the constriction and separation of the skin- and muscle-layers is completed, a short length of the intestine usually remains for a time connecting the two pieces; it may rupture close to one of them, or may disintegrate completely. The point to be noted is, that the resultants of the division do not move apart, but remain quiescent.

Lastly, after considerable searching, I found in the field one case in which division had evidently just been completed. The halves were still joined by an exposed portion of the gut.

On the basis of all this evidence there is certainly reason to believe that *Holothuria surinamensis*, in the adult state, normally multiplies its numbers by a process of binary fission. The resulting organisms readily complete their missing parts, but probably do not undergo a second division until after the lapse of a considerable interval, if they do at all.

It would be of some interest to determine the nature of the sexual products in the animals which thus result from division.

AGAR'S ISLAND,
BERMUDA

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RHEOTROPIC RESPONSES OF EPINEPHELUS STRIATUS BLOCH

HOVEY JORDAN

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CONTENTS

I. INTRODUCTION

A. The problem

The tropical fish known as hamlet or grouper (*Epinephelus striatus* Bloch) is very favorable for biological experimentation. It is easily obtained and is a hardy animal; in response it is deliberate, but definite. When considerable numbers of hamlets are held in confinement they often manifest a tendency to crowd together closely, though without any regular arrangement, their heads pointing in all directions. This characteristic may have helped to give them the common name of "grouper."

While engaged in a study of the reactions of this fish, in connection with certain work on its central nervous system, I made use of an apparatus of the following nature: In a large spawning trough (fig. 1, *A*), such as is used in fish hatcheries, I suspended by two supports (*B*, *B*) a cage (*D*), about 36 inches long by 18 inches wide and 10 or 12 inches deep, made of galvanized "chicken wire." A current of fresh sea water was introduced at one end of the cage, at an angle of about 30° with the horizon, by a 1-inch hose pipe, for the purpose of affording a better supply of water than was furnished by the sluggish current of the trough, flowing in the same direction.

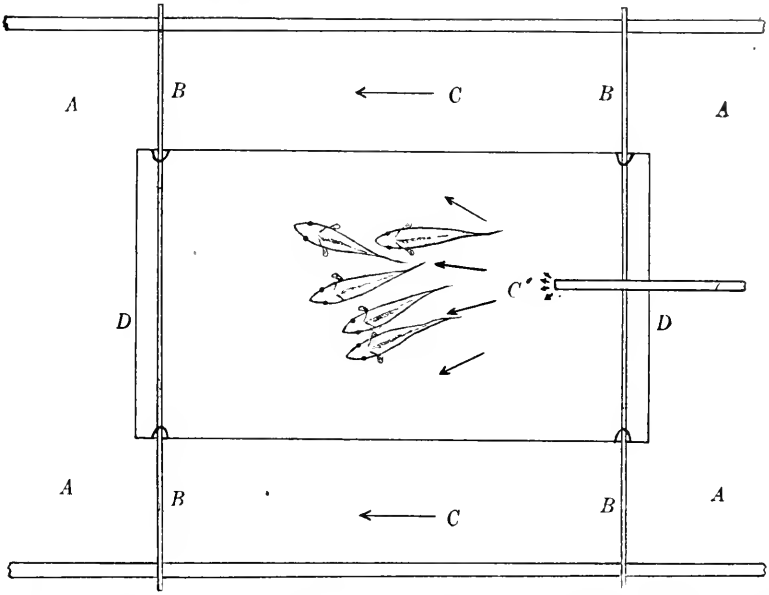

Fig. 1. Diagram of cage as seen from above. *A*, Large spawning trough; *B*, rods supporting cage; *C*, current of spawning trough; *C'*, additional currents from hose pipe; *D*, wire cage suspended from *B*.

When several normal fishes had been put in the cage for temporary storage, it was noticed that their orientation was no longer promiscuous, as in quiet water, but that an unusual position was assumed by nearly all of them (fig. 1). The cause of this was not at once apparent; but a little experimentation showed that the new orientation was in response to the stimulus of the seawater delivered through the hose pipe. Contrary to the usual rheotropic response of fishes, they had their heads directed *away* from the hose pipe, most of the time with the body axis in line with the current, so that a group of fishes showed a fanlike arrangement corresponding to the spreading currents of water *C*, as shown by the arrows in figure 1.

In order to determine the exact nature of this reaction, experiments were undertaken both on groups of fishes and on individuals. The study of groups showed that this peculiar orientation was not altogether constant, but that some of the fishes assumed from time to time positions more or less oblique to the current. The precise significance of this was manifest only when the actions of individual fishes were observed continuously.

In an effort to ascertain the precise mechanism by which these reactions were brought about, and if possible to determine the nature of the stimulus inducing them, a small but strong localized current of water was directed in succession against different areas of the body. This revealed varying sensitivity on different areas; furthermore the effect of a narcotic on these areas indicated both the position and the probable nature of the end organs involved in these responses.

B. Review of literature

Up to about fifteen years ago it was generally held that the orientation and locomotion of organisms in a current of water—whereby the anterior end is directed against the current and a swimming motion causes either an advance or the maintenance of a comparatively stationary position against the flow—was due to the direct mechanical action of the current and was in the nature of a reaction to pressure. Stahl in 1884 described such a phenomenon in Myxomycetes and Verworn (1) in his Allgemeine Physiologie (p. 428) interprets it as a positive response to pressure stimulation. Lyon (2) (p. 157) says that reactions of blinded fishes [Fundulus?] to currents flowing through troughs may *perhaps* be caused "by higher pressure on one part than on the other, through differences in the velocity of the water striking the two parts." He here introduces the theory of unequal pressures on various parts of the fish's body in contrast with "the gross mechanical one of Radl."

The one early exception to the theory of pressure stimulation by currents seems to have been the idea advocated by Schulze (3), that the lateral-line organs were stimulated by the movement of water against them. This view has, however, been adequately disproved by Parker (4).

In the same year Tullberg (5) (p. 20) carried out experiments in which he eliminated the ear of certain fishes and found the operated animals to be insensitive to water currents. He therefore concluded that the ear is the chief receptor of this stimulus, which in his opinion affects principally the cristae acusticae of the ampullae. Parker (6) (pp. 202–203) contended, on the other hand, that the failure of fishes to orient in a normal fashion to the current when their ears had been destroyed is caused by an interference with the ear, "though the primary stimulus for this form of response might be received by the skin."[1]

In confirmation of this view—i.e., primary cutaneous sensitivity to currents—he (4) (p. 61) showed that specimens of Fundulus heteroclitus in which the lateral-line nerves had been severed responded normally,—i.e., swam against the current in a glass tube,—and he (6) (p. 202) also succeeded, after cutting of the lateral-line nerves and the spinal cord (in an anterior region), in inducing normal responses to a current of water directed against the sides of the body posterior to the cuts. Moreover, he excluded the possibility of stimulation through the ear or lateral-line senses by severing the appropriate nerves and draws this conclusion (4) (p. 63): "Surface waves and current action" . . . . "must stimulate the general cutaneous nerves (touch)."

However, his attempts to inhibit the action of the cutaneous nerves by the application of cocaine, and thus to show directly what the indirect method (the elimination of ear and lateral-line organs) had rendered probable, were unsuccessful.

In 1904 Lyon, basing his conclusions upon the results of ingenious experiments with Fundulus, scup, stickleback and butterfish surrounded by movable environments, put forward another and totally new explanation of rheotropism. He contended that "the primary cause of orientation [and locomotion of fishes] in streams of some uniformity of motion is an optical reflex." "The essential element of stimulation is the environment [apparently moving, but in reality stationary], not the currrent;" the latter "does not directly stimulate." He, however, adds that cutaneous sensations [touch?]—contact of the body with stationary solid objects and even "the sliding contact between fish and [rushing] water"—may sometimes be the cause of such orientation and locomotion. But even these responses, like those of a strictly optical reflex nature, are to be regarded, he thinks, as

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[1] i.e., stimulation of the skin (tactile corpuscles) directly by small currents. This, it should be noted, is different from the indirect (optical reflex or thigmotropic—by solid object) stimulation, which is described below.

compensating motions; "the current playing only the passive part of sweeping the fish against objects on the bottom."

In view of Lyon's observations and general conclusion that the current itself does not stimulate the skin of Fundulus directly, except as it acts like a solid object of considerable size, it seems desirable to determine whether, in other fishes, the integument is sensitive to water-currents, and also whether the eyes have any essential part in the rheotropic reactions.

II. DESCRIPTION OF EXPERIMENTS

A. Posterior[2] *and lateral orientation*

1. In groups of fishes. The positions assumed by a group of fishes under the conditions already described gave, in general, the fanlike appearance shown in figure 1; but it was also to be seen that, from time to time, one or more individuals assumed a different position, the body swinging around so that its long axis was almost or quite perpendicular to the current; and sometimes, though rarely, an individual would be headed more or less directly into the current in the manner of the hitherto described reactions of fishes generally. In order to test roughly the quantitative relations at any given instant between these various positions, several series of observations were made, both during the day and at night, on a group of seven fishes which had become habituated to their surroundings. One such series is recorded in table 1; all the others are nearly identical with it.

From table 1 it will be seen (1) that, although the majority of fishes (67.1 per cent) tailed into the current, many individuals (31.9 per cent) so placed themselves that the current hit the side of the body; and (2) that less than 1 per cent headed into the current. These records were taken at about two-minute intervals. While they show that the hamlet in its normal responses to a current may assume one or the other of two positions, they do not afford sufficient evidence of

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[2] In describing the various positions of orientation which a fish may assume, I shall use *posterior* orientation to denote positions in which the tail is directed toward the oncoming current or to points not more than 45 degrees from it on either side; *lateral* orientation to denote positions in which the long axis of the body is perpendicular to the direction of the current or makes an angle with the perpendicular on either side not greater than 45 degrees; and *anterior* orientation to positions whereby the head is directed straight into the current or to points not more than 45 degrees from it on either side.

TABLE 1

Successive positions of orientation of a group of seven hamlets observed at about two minute intervals

	NUMBER OF INDIVIDUALS IN EACH OF THE THREE POSITIONS AT THIRTY SUCCESSIVE COUNTS																														TOTAL	AVERAGE	PER CENT
Number of the observation...	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	210	7	100
Orientation																																	
1. Posterior...	6	6	4	3	5	6	5	5	4	4	5	5	5	5	6	5	6	5	4	6	7	5	2	3	5	2	3	5	4	5	141	4.7	67.1
2. Lateral.....	1	1	2	4	2	1	2	2	3	3	2	2	2	2	1	2	1	2	3	1	0	2	4	4	2	5	4	2	3	2	67	2.2	31.9
3. Anterior....			1																				1								2	0.06	0.9

the exact nature of this reaction—whether the two positions are due to differences between individual fishes or are phases of one reaction. Single groupers, however, when studied continuously showed that both positions are assumed in the course of one reaction.

2. In individual fishes. Individual hamlets were tested in a spacious oblong aquarium (fig. 2) provided with plane glass front and back to allow uninterrupted observation from the sides as well as from above. A glass tube 1 cm. in diameter and so directed as to make about equal angles with two adjacent sides of the aquarium, delivered a strong current (*C*) diagonally across the tank. The volume of this current was approximately 0.1 liter per second. It is the only one which is significant for the purposes of this investigation. Those peripheral to this were not of sufficient strength or regularity to influence the fish in any consistent manner. These currents were studied by the use of floating and suspended objects, and the results plotted show their main features.

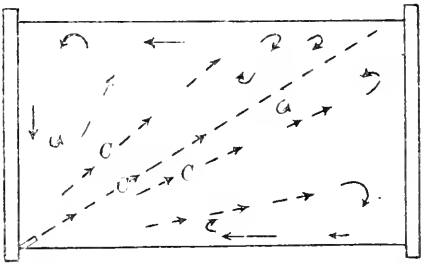

Fig. 2. Diagram of aquarium (20 by 30 inches) and currents as seen from above. *C*, Main diagonal current.

The fish under investigation (fig. 3) seemed to prefer the region of the strongest current; that is, it remained near the source of the current, shifting from one position of quiet to another, settling to the bottom, or remaining suspended at a fixed place in the current for a few moments, and then again changing position slightly. All the while, however, the fish assumed either posterior or lateral orientation to the main diagonal current (*C*). It held this position in the tank indefinitely. When left in the current for two or three hours no change of general position was noted. When the current was shut off, the fish under investigation would swim to the bottom or to one of the corners of the tank, where it would remain relatively quiet. In figure 3, one out of several records is reproduced to show a typical reaction. The diagonal line (*C*) shows the direction of the main current. The elapsed time in minutes, from the beginning of observations, is given in table 2 for each of twelve successive positions. These positions are indicated in figure 3 by straight lines, the anterior end of the fish being denoted by a short cross line, and the successive positions by consecutive numerals placed near the end representing the tail.

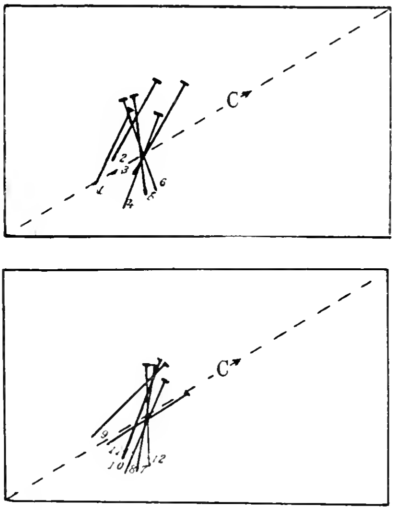

Fig. 3. Twelve successive positions occupied by a normal fish with reference to the main diagonal current, *C*. To avoid confusion only six positions are indicated on each of the two diagrams. Position 11 was retained longer than any other; it is therefore regarded as the most significant orientation. One complete reaction is regarded as occupying the interval of time between two successive assumptions of such a position.

It should be noted, however, that in this particular experiment, contrary to the most of them, the percentage of posterior and lateral orientations is nearly equal. That posterior orientation is the purpose of shifting the position, is suggested by the fact that the fish remained stationary for a considerable time only when it was almost directly tail into the current, position 11. After this period (about two minutes) it again begins a series of changes in position, like those shown in figure 3, which lasts for about four minutes, whereupon another period of rest ensues. What I have called one complete reaction, then, requires about seven minutes. It is most important to note that the fish did not at any time head into the current.

The two different experiments, one with groups and the other with individuals, are consistent in showing that posterior and lateral orientation to a current is the normal reaction of *Epinephelus striatus*.

TABLE 2

Time elapsed in assuming the positions, 1 to 12, shown in figure 3

	NUMBER OF THE POSITION											
	1	2	3	4	5	6	7	8	9	10	11	12
Elapsed time in minutes	0	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	3	$3\frac{1}{2}$	$3\frac{3}{4}$	$4\frac{3}{4}$	7
Time intervals between positions in minutes		$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{1}{4}$	1	$2\frac{1}{4}$

B. *Experiments on regional sensitivity*

A study of the relative sensitivity of various parts of the body was

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AUTHOR'S CORRECTION

(Insert opposite page 444, Volume xliii, 1917)

The sentence (page 444, paragraph 2) beginning: "It should be noted, however," should be interchanged with the first part of a sentence on page 450 (paragraph 1), viz., with "It should be noted that . . . . the positions were posterior."

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was provided with a hole for observation; the tube was nearly invisible. In all cases the local current stimulation produced a negative reaction, a swimming or backing away from the current. It is possible, however, to divide the body into five regions based on their relative susceptibility to stimulation by such a current. In the order of promptness of reaction these are as follows: lip region (seven seconds); caudal fin (sixteen seconds); dorsal fin, posterior part (twenty-two seconds);[3] cheek and operculum (twenty-five seconds); sides of body (about thirty seconds). The belly was not tested because of its inaccessibility. Thus it appears that the lip region is by far the most sensitive part of the integument tested. If stimulation of the lips is prolonged, the hamlet becomes very vigorous in its attempts to escape.

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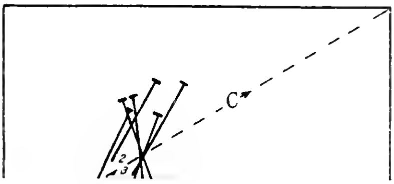
[3] That the fins are not essential in rheotropism is indicated by the fact that when either dorsal or caudal fins are removed, the normal reaction is unaltered. It was also noticed that fishes whose fins had become badly frayed by long captivity were normal in their responses to currents shown in figure 3.

main diagonal current (*C*). It held this position in the tank indefinitely. When left in the current for two or three hours no change of general position was noted. When the current was shut off, the fish under investigation would swim to the bottom or to one of the corners of the tank, where it would remain relatively quiet. In figure 3, one out of several records is reproduced to show a typical reaction. The diagonal line (*C*) shows the direction of the main current. The elapsed time in minutes, from the beginning of observations, is given in table 2 for each of twelve successive positions.



occupied by a normal fish with reference to the main diagonal current, *C*. To avoid confusion only six positions are indicated on each of the two diagrams. Position 11 was retained longer than any other; it is therefore regarded as the most significant orientation. One complete reaction is regarded as occupying the interval of time between two successive assumptions of such a position.

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The two different experiments, one with groups and the other with individuals, are consistent in showing that posterior and lateral orientation to a current is the normal reaction of *Epinephelus striatus*.

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Time intervals between positions in minutes		$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{2}$	1	$\frac{1}{2}$	$\frac{1}{4}$	1	$2\frac{1}{4}$

B. Experiments on regional sensitivity

A study of the relative sensitivity of various parts of the body was undertaken with the hope of finding some evidence as to the nature of the causes which produce this peculiar rheotropic reaction. The method employed to determine the sensitivity of different areas of the surface of the fish to a current was to direct a jet of water at close range against limited areas (approximately 25 sq. cm.) and to note the response, if any. For this purpose a long glass tube with a bore 1 cm. in diameter was used, and the average flow of water through it was roughly 1/28 liter per second. In this way all parts of the dorsal and lateral surfaces were explored. To prevent as far as possible any complication that might result from sight stimuli, the observer was screened from the fish by a curtain covering the side of the tank. The curtain was provided with a hole for observation; the tube was nearly invisible. In all cases the local current stimulation produced a negative reaction, a swimming or backing away from the current. It is possible, however, to divide the body into five regions based on their relative susceptibility to stimulation by such a current. In the order of promptness of reaction these are as follows: lip region (seven seconds); caudal fin (sixteen seconds); dorsal fin, posterior part (twenty-two seconds);[3] cheek and operculum (twenty-five seconds); sides of body (about thirty seconds). The belly was not tested because of its inaccessibility. Thus it appears that the lip region is by far the most sensitive part of the integument tested. If stimulation of the lips is prolonged, the hamlet becomes very vigorous in its attempts to escape.

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[3] That the fins are not essential in rheotropism is indicated by the fact that when either dorsal or caudal fins are removed, the normal reaction is unaltered. It was also noticed that fishes whose fins had become badly frayed by long captivity were normal in their responses to currents shown in figure 3.

When "cornered" by the current it literally stands on its head, a termination of the negative reaction which is extremely unusual among fishes.[4] This high sensitivity suggests at once an explanation of posterior and lateral rheotropism, for it may be that stimulation of the lips by the current in the aquarium or cage was so strong as to produce decided irritation, and thus to cause the fish to place that portion of its skin in a less exposed position.

C. Summary of normal rheotropism

The foregoing experiments show:

1. That to a moderate artificial water-current a normal orientation of *Epinephelus striatus,* in groups or individually, is posterior or lateral, as phases of one complete reaction, but almost never anterior.
2. That the lips are the most sensitive integumentary region, other regions being less sensitive in the following order; tail>, dorsal fin>, side of head>, middle of body.
3. That the peculiar posterior and lateral reaction to a current is perhaps an attempt to protect from the current the highly sensitive lips.

D. The end organs concerned in rheotropism

1. Method of determination. In searching for the end organs concerned in rheotropism, it was, of course, necessary to consider all possible sensory cells. My conclusions relative to the significance of equilibration (semi-circular canals), muscle sense, and pressure sense in these reactions are, for the most part, based upon observations only. The lateral-line organs, eyes and cutaneous receptors, on the other hand, were experimentally eliminated, and each operated fish was carefully studied to detect any resulting variation of the response from that of the normal individual. It was established by these experiments that the end organs concerned in rheotropism in the hamlet are located in the integument and are probably the tactile corpuscles.

2. Observations and experiments: a. Observations. When confined in large volumes of still water, groupers are seen usually to lie inactive on the bottom of the tank. In captivity they swim about very little, seem-

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[4] It is important to note that the same reaction can be induced by the use of a fine glass rod (tactile stimulation), and also that the variation in regional sensitivity to such stimulation corresponds exactly to that described for stimulation by the current.

ing to prefer muscular repose to exertion, the fin movements being few and slow; pectoral fins are vibrated about twenty-three times per minute. The application of a localized current of little force was sufficient to start the fishes from a position of complete rest, but when they were beyond the range of the current, they again settled to the bottom. This behavior indicates that the agreeableness of muscular effort is not sufficient to cause any prolonged swimming. On the other hand, the exertion and possible fatigue involved in maintaining a relatively constant position in a current which is broad enough to cover the whole fish might be expected eventually to produce a negative reaction. Instead of this, however, the fishes remained for an hour or two in the strongest part of the current (fig. 3), seeming to prefer it to the quiet water. This leads one to the conclusion that the muscular effort necessitated in these reactions is not in itself a deterrent factor. Many times, too, when a localized current was directed against the side of the fish, lying at the bottom near the wall of the aquarium, it was observed that one of the pectoral fins—extended horizontally to the wall—served to keep the body of the fish from contact with the side of the tank. In these cases the effort involved in maintaining this position did not cause the reaction time to vary.

With a view to ascertaining what importance, if any, attaches to the pressure sense, I made use of a current of water directed through the glass tube (1 cm. in diameter) already referred to in other experiments. If the pressure sense is a factor in rheotropic response, it is to be expected that the response to a very strong current would be more prompt than to a weaker one. Accordingly I repeatedly subjected the same fish successively to a weak current (about 1/28 liter per second) and to a stronger one (about 1/8 liter per second). Though the latter was of sufficient force to produce an appreciable indentation of the skin and musculature of the body, the reaction time was not shorter than in the case of the weaker current. I may also add that fishes can be pressed by the hand against the side of the aquarium with considerable force without causing any definite response. In his study of the pressure sense as a possible cause of rheotropism, Lyon (2) (p. 154) enclosed fishes (silver sided minnows) in long stoppered bottles which were floating down the stream. He found that under these conditions, with all pressure stimulation thus eliminated, the fishes responded normally, by swimming in a direction opposite to the drift of the bottle, in an attempt to keep the visual environment constant. My experiments, though not of such fundamental importance as Lyon's, tend to substantiate his conclusion that [considerable] pressures do not cause or influence the rheotropic reactions.

Observations were also made upon the equilibration of hamlets. They were studied in still water and when subjected to a current sufficiently strong to cause a change in the direction of the dorso-ventral axis. Any differences between the rheotropic response of fishes whose dorso-ventral axis is normal and those in which this axis has been displaced would suggest that the organs of equilibrium may be involved. An individual fish when in quiet water usually lies in such a position that its dorso-ventral axis makes an angle of 10° to 15° with the normal (fig. 4). When this angle was doubled by a current from a glass tube directed against the side of the fish there was no variation in the time required to produce a negative reaction. Moreover the motion which restores the fish to an approximately vertical position usually follows, and never precedes, this rheotropic response; whereas, if the fish is carefully put in the same oblique position by a slow displacement with the hand, instead of by the current, the righting movement takes place much more promptly. It seems, then, that any slight disturbance in the hamlet's equilibrium which the current might cause would neither produce nor in any way affect the observed behavior. This conclusion is in accord with Parker's conclusion (6) (p. 203) to which reference has already been made.

b. Experiments. Lateral-line organs can be excluded from the list of possible rheotropic receptors for two reasons: First, when the current is directed immediately against the lateral-line canal upon a limited mid-body area, the slow response (thirty seconds) characteristic of regions both dorsal and ventral to the lateral-line, but excluding it, is neither quickened nor retarded. Secondly, a hamlet in which all of the lateral-line nerves had been severed responded normally to the current. This experiment confirms Parker's results (4) (6) from a similar test made upon Fundulus.

In order to determine whether the visual organs are essential to these reactions, experiments were also performed successively on several individuals after enucleation of both eyes. Fishes thus blinded were subjected to conditions of stimulation identical with those in the tests which were made upon unoperated hamlets (fig. 2) and the successive positions which they assumed were recorded. One of these records is reproduced (fig. 5, table 3) for comparison with figure 3, which shows the consecutive orientations of a normal fish in a like environment.

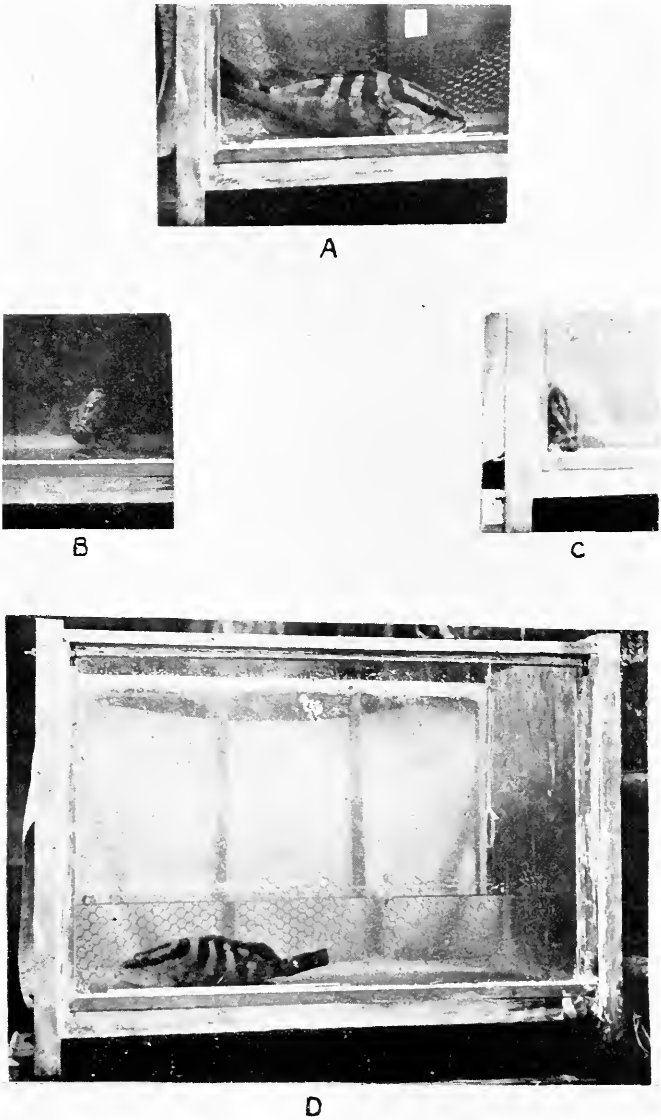

Fig. 4. Photographs of resting fishes tipped at a characteristic angle from the vertical. *A*, Side view; *B* and *C*, front views; *D*, side view of fish, showing the whole aquarium.

The two records, while showing slight variations, are remarkably alike in the time of response and the number of different positions assumed in changing from an almost lateral orientation to an approximately posterior one. It should be noted that in this series of orientations 75 per cent of the positions were posterior, and that, as in figure 3, no anterior positions were assumed. It seems, then, that the eyes of the hamlet are not the essential rheotropic end organs.

In an effort to locate the cells which are stimulated by the current, the skin was stripped from one of the more sensitive body areas. It was impossible to obtain any response from a current which was directed against the subcutaneous structures (muscles, etc.) thus exposed. In a few cases indefinite reactions, which were much slower than normal, were observed, but they were not characteristically rheotropic in nature. These results lead one to the conclusion that the end organs concerned in rheotropism are located in the integument.

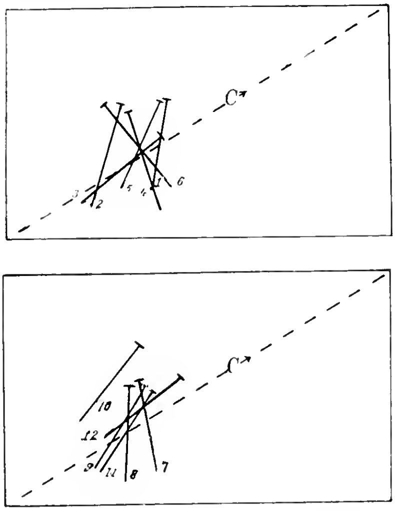

Fig. 5. Twelve successive positions assumed by a blinded fish in response to the current C. As in figure 3, only six positions are shown in each diagram.

TABLE 3

Time elapsed in assuming positions 1–12 (fig. 5)

	NUMBER OF THE POSITION												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Time elapsed in minutes	0	$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	7
Time intervals between positions in minutes		$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$2\frac{1}{2}$

The problem of determining the particular type of sense organ which is sensitive to these currents is resolved, then, into a physiological study of the hamlet's cutaneous end organs. Of these only the tactile corpuscles are significant, because the receptors for chemical, photic and thermal stimuli plainly can not be involved in these rheotropic responses.

It has been stated previously that the areas of greatest cutaneous sensitivity in the case of both touch and current stimulation have the same distribution. Cocaine is known to inhibit the functioning of the end organs of touch. It was, therefore, used to eliminate, functionally, the tactile corpuscles, in order that their relation to rheotropism might be determined. Of all available areas the lips were chosen for the application of this reàgent because the experiments had shown that their stimulation gave the most marked and peculiar responses. Whether the lips are stimulated by a fine glass rod or by a moderate water current, the fish performs the very curious reaction of either backing away violently or of standing on its head. The method of treatment with the cocaine was as follows: the fish was removed from the experiment tank and the lips were immediately immersed in a 0.1 per cent solution of sulphate of cocaine for about ten seconds; this was supplemented by bathing the lips with the same solution applied by means of a soft cloth at about ten-second intervals for fifty seconds. After this treatment the fish was returned to the tank and its responses to stimulation by a glass rod and by a weak current (about 1/28 liter per second) were noted. By a repetition of the treatment it became evident that there was a slowing down in time of response with increased exposure to the solution and that this was precisely the same for both types of stimulation. Two repetitions of the first treatment—in all about three minutes—were usually sufficient to inhibit completely all responses to either type of stimulation; neither the glass rod nor the localized current then produced any reaction. In subsequent trials the lips were treated continuously—without periodic subjection to stimulation—for a period of about three minutes. The effect was the same as in the preliminary treatment just described. After such administration of cocaine the fish swam about in a slightly abnormal manner, manifesting an irritation due, doubtless, to the drug. This insensitivity of the lips lasted about a minute, sometimes a few seconds longer. Then a gradual functional recovery occurred until, at the end of three to four minutes, normal responses could be obtained by the use of either stimulus. It is most significant that the time of disappearance of normal sensitivity, as well as that of its reappearance, was absolutely the same for both kinds of stimulation.

This fact indicates that those sensory cells which are stimulated by touch and defunctionized by cocaine are also the cells which are the primary end-organs of the rheotropic response.

3. Summary of end-organ determination. 1. The end organs of the hamlet essentially concerned in rheotropism are located within the integument.

2. The regional distribution of sensitivity to a water-current and to touch is the same.

3. Cocaine applied to the lips for about three minutes renders those organs insensitive both to touch and to currents.

4. These facts indicate that the end organs of touch serve also as the essential end organs of current stimulation in the hamlet.

5. Other sensory cells may be more or less affected by currents in some fishes, but they appear to be only accessory end-organs of rheotropism, and in the responses described in this paper they evidently play no part at all.

III. DISCUSSION

There is much evidence to show that the rheotropic responses of the hamlet, as suggested for Fundulus by Parker (4) (6), are effected chiefly by the tactile corpuscles. His attempt to prove this by immersing the entire fish in a solution of cocaine did not succeed because the general action of the drug entirely destroyed all sensitivity and movements of the fish; but the great sensitivity of the lips of the hamlet has afforded an excellent opportunity to study changes in the fish's behavior resulting from the local application of this narcotic. In this case regional anaesthesia, producing insensitivity to touch, is as satisfactory as general narcotization would be, because it causes a most unique rheotropic response totally to disappear.

Some of Lyon's experiments (2) on rheotropism, from which he concluded that the reaction of Fundulus to currents is chiefly to compensate the transporting effect of the current, seem to furnish evidence that the integumentary cells (tactile corpuscles) were directly concerned in the rheotropism which he observed. Among these is experiment 9 (p. 157), in which a blinded fish, without touching any solid object—often required for orientation by fishes without eyes—headed into the rushing current. This certainly may be interpreted as a response to direct tactile stimulation of the integument by the water, and Lyon himself admits that this may be called a *true* rheotropism. In his opinion, however, it is due to the "sliding contact" (stereotropism) between fish and water, although he admits the possibility of another interpretation involving the idea of unequal pressures on different parts of the body of the fish. Whether the rheotropism induced by this "sliding contact" is the equivalent of stereotropism, with which Lyon believes it is closely related, is a question needing further investigation.[5]

The comparative importance, in the behavior of Fundulus, of these two types of impressions—optic and cutaneous—is, I think, suggested by some of Lyon's interesting experiments. An example of this is his experiment 3 (p. 153). Here a normal fish, surrounded by a rapidly moving artificial environment, is immersed in a current of water flowing in the same direction as the environment, but less rapidly. The fish swims in the direction of, but faster than, the current flow, following the moving environment in rate as well as direction. This is unquestionably a case of optical response. When the environment stops moving, the current still flows on in the same direction, but with a gradual decrease of speed due to friction; but the fish, having been carried passively by the current, turns, without a reference point, and faces [swims against?] the current. This may be due, as Lyon says, to an apparent reversal of the visual field; but, since *blinded* fishes (experiment 9), *without* touching a reference point, also orient against the current, it seems equally logical to interpret the turning of fishes with eyes (experiment 3) as the result of the normal rheotropic response to direct tactile stimulation of the integument, which had, during the movement of the optical field, been subordinated to the sight-reflex.

If this be a proper interpretation of the results with Fundulus, we have in the hamlet a reversal of the relative importance of the two kinds of stimuli. Here, under the experimental conditions described, all optic stimuli were, apparently, subordinated to tactile impressions; the direct effect of the current being predominant and able to cause entirely normal reactions in the absence of eyes. It is, however, not quite satisfactory to compare the two sets of experiments (those by Lyon and by myself) from this point of view, because the relative amounts of cutaneous and optic stimuli in each are indefinite and variable. It is certain that, in my experiments, there was relatively little stimulation of the eyes, because the fish remained in an approximately

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[5] It seems probable that the currents of a narrow trough would not be sufficiently strong nor distinct from one another to simulate solid objects, but that there would be an almost insensible gradation between them.

constant position, and that, in Lyon's movable-environment experiments, their total stimulation was much greater. It can not be said whether the tactile corpuscles were subjected to a proportionate stimulus or not. It may be that the hamlet, too, would orient to a movable environment regardless of contemporaneous tactile stimulations[6] by the current; but the facts remain that the tactile-corpuscles do, of themselves, effect orientation, and that this orientation under the above circumstances is unaltered by the presence of eyes. This orientation, it seems to me, is caused by a direct stimulation of the integument by the water currents as such, and to it we should apply the term rheotropism. The response so well described by Lyon as due to optic reflex might then be called a rheoscopic response in view of the fact that it is due to the optical effect of a flowing or moving environment.

How the current stimulates these tactile end organs is still a matter of speculation. It may be that differences of velocity in different portions of a current provide slight local variations of force sufficient to cause a definite response on the part of the fish. How the stimulation results in orientation is a further question, for the mechanism and sensation may or may not be the same for rheotropism that they are for stereotropism.

The author wishes to express his appreciation to Dr. E. L. Mark for the privilege of working at the Bermuda Biological Station, and to Dr. Mark and Dr. W. J. Crozier for valuable assistance and advice in the work.

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[6] It would be interesting to determine the relative importance of the eyes and cutaneous elements (tactile corpuscles) as sense organs in the orientation and rheotropic motions of many other fishes.

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THE BEHAVIOR OF HOLOTHURIANS IN BALANCED ILLUMINATION

W. J. CROZIER

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I. The behavior of phototropic animals when so situated as to be illuminated from opposite directions gives important information regarding the nature of the mechanism of stimulation. It was held by Loeb (1) that a phototropic organism, when placed at the center of the line joining two equal sources of illumination, should move in a direction perpendicular to this line. The accuracy with which this kind of response is obtainable in a suitable organism is demonstrated by Patten's (2) experiments with the negatively phototropic larva of the blowfly. Patten further found that the angular deflection of the larva's path from the perpendicular was so related to the percentage difference in intensity between the two lights, when these intensities were caused to alter in a graded series of ratios, as to produce a smooth curve when these values were plotted on the axis of ordinates and abscissae, respectively. On the basis of this graph, and taking into account the blowfly larva's method of locomotion, Patten was able to show (3) that the responses appear to be determined by the presence of two photosensitive surfaces inclined to each other at a definite angle. The definite path of progression adopted by the larva under the influence of two opposed unequal beams may be predicted on the assumption that the animal ceases to deflect from its original locomotor path—which in these experiments is a straight line normal to that connecting the sources of light—as soon as the luminous intensity on these mutually inclined surfaces is made equal by the larva's position.

II. There may be deduced from this principle the corollary that, if the photoreceptive surfaces of an animal are so arranged as to be sensibly *parallel*, no definite position should be assumed by this organism when bilaterally illuminated. For, in such a case, if the balanced lights were *equal* in intensity, it would be impossible for the animal to place itself in a position which would result in unequal illumination of the two sides; while, if the lights were *unequal*, the amount of light received by either side could not in any position be made equal to that incident upon the other. It is assumed, of course, that the longitudinal axis of the animal remains straight when orientation is completed.

Thus an animal of this kind might be clearly phototropic according to other criteria, and yet fail to satisfy the requirement of orientation under bilateral illumination which Loeb's contention demands. The existence of such organisms, however, would add further support to the assumption made by Patten, namely, that the exhibition of a definite path of locomotion under these conditions depends upon the final equality of illumination on each of the two photosensitive surfaces.

III. Certain pedate holothurians have been found to be different from most other echinoderms, in that they exhibit a pronounced bilaterality in their structure, coupled with a fixed direction of progression (4), (5), (6). Typical tropistic behavior is thus made possible. It has been shown that some of these holothurians (Holothuria surinamensis, H. captiva) are photo-negative, that they are sensitive to light over their whole surface, that they give well defined reactions to shading, and are non-reactive to a sudden increase in light intensity, yet orient away from the light with conspicuous precision. It is impossible to conceive, as I have already pointed out (4), that these animals are oriented by light in any way other than through the direct action of illumination upon their integument.

One of the holothurians referred to, H. captiva, is the most outstandingly bilateral of all the species which I have studied. Its lateral surfaces are so nearly straight and parallel that, to all intents and purposes, they may be regarded as strictly so; that is, longitudinal elements of its surface are parallel. I have previously described the accuracy with which it orients away from the light. Experiments were subsequently made to determine the behavior of this species when illuminated from opposite sides.

Inasmuch as the whole surface of H. captiva is sensitive to light, the higher sensitivity of the oral end should not greatly obscure the interpretation of such experiments. When horizontal light is employed, the sides of the animal may be regarded as equivalent to two photosensitive areas. This particular species of holothurian, fortunately, tends to preserve a straight position of the body.

In my present study upon this animal, the tests were made in a dark room, the animals being placed in a flat-sided aquarium with their long axes perpendicular to the line connecting the two sources of light. The lights used were two tungsten incandescent filaments, placed at various distances from the holothurian in different experiments. In some cases the animal was induced to begin crawling in a direction perpendicular to that of the light beams before the latter were turned on. The intensity of the lights was varied by using filaments of different wattage (25 to 100 watts). Since the characteristic features of the results soon became evident in these experiments, no great refinement was necessary in the physical precision of the light adjustments.

IV. In no case did Holothuria captiva assume a path of locomotion definitely related to the intensities of the acting lights. In no case was it constrained to move, after the fashion of the blowfly larva, along a path inclined to the direction of the beams. A number of animals were found to move first toward one light, then toward the other; this was the case when the lights were of nearly equal intensity. Many individuals circled in an aimless, indeterminate way (as when illuminated from above), while others became curled into the shape of the letter S, the oral end, and frequently the cloacal end as well, being bent away from the stronger light.

When the intensity of the stronger illumination was made eight or nine times that of the weaker one, the holothurians almost invariably oriented precisely and away from the stronger light. But when they had moved somewhat toward the weaker light, their movements became quite irregular.

To meet the criticism that possibly the incandescent filaments as sources of light were too small as compared with the size of the animals, the latter being 6 to 8 cm. in length, experiments were tried with sunlight reflected from two mirrors, each measuring 15 by 20 cm. The holothurians were in a dark chamber, an opening on either side (10 by 8 cm.) allowing the sunlight reflected from the mirrors to enter the box from opposite directions. One or several lightly smoked glasses were then interposed between one mirror and the corresponding opening in the dark chamber. The behavior of the holothurians under these conditions was qualitatively identical with that in the trials with electric lights. Hence I conclude that H. captiva does not maintain a predictable path of locomotion under the influence of bilateral illumination.

V. The validity with which this result may be applied to the criticism of photic stimulation theories depends largely on the share taken by the general surface of the animal in photoreception. That this share is a considerable one, is shown by the following:

a. Excised pieces of the "dorsal" integument (including skin and muscle layers) which have been cut from the midbody surface of H.

surinamensis or H. captiva exhibit local wrinkling contractions when a spot of intense light is thrown upon them. The wrinkling movements cease when the strong light is removed. When first prepared, the pieces of the body wall are strongly contracted; but if they be allowed to lie in seawater for half an hour or so, or if they be subjected to gentle traction, they become somewhat relaxed, although the cut edges remain curled. It was on such relaxed preparations that the light test was made. Tube feet on isolated portions of the "ventral" surface also bend away from the light.

b. A phenomenon closely akin to "circus movements," and probably in principle identical with them, appears when these holothurians are exposed to general illumination from above, provided one side of the animal's surface has been rendered insensitive to light. In the narcotizing, cocaine seems to give the best results, but chloretone was also used. In the case of either narcotic, a strong solution (in seawater) was employed and the holothurian, while being held out of water, had one side painted over with the solution several times. The parts so treated soon become quite insensitive to light, while the untreated side is still sensitive, and its tube feet all remain normally functional. On being returned to seawater the holothurians soon assume a curved attitude, the narcotised side being the relaxed one (convex). If the animals are then strongly illuminated from above, they rapidly become curved in the opposite direction, the narcotised side being then the inner, contracted (concave) portion of the bend. Thus the holothurian bends toward the *unstimulated* side, whether the non-stimulation is determined by the relative absence of light, or by the enforced incapacity of its photoreceptors.

VI. These experiments afford evidence: (1) that the amount of light received by the photosensitive surface of Holothuria surinamensis and H. captiva determines their behavior in an illuminated field; (2) that the assumption of a definite path of progression, with respect to balanced illumination, depends on the non-parallel relation of photosensitive surfaces.

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With Six Plates.

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Bermuda consists of a little group of islands of not more than twenty square miles of dry land, lying in latitude 32° 14′–32° 23′ north and longitude 64° 38′–64° 53′ west, about 700 miles southeast of New York, and 600 miles east of the coast of South Carolina. They are some three or four hundred miles south and east of the Gulf Stream. This situation accounts for the very marked uniformity as well as the mildness of the climate of the islands.

All of Bermuda now above sea level consists of limestone, from a fine sand to hard crystalline rock. The lime comes from the various organisms inhabiting the water, in part animal but more largely vegetable;[1] many of these lime-producing algae are included in the following pages, but Lithothamnium and its allies, stony algae belonging to the Florideae, which furnish the larger part of the material, we have not been able to include here. The fine powder formed from the remains of these various organisms is carried by the wind and spread out over the ground. Rainwater dissolves a certain amount of it, which when the water dries up is deposited and acts as a cement. Crystallization goes on more or less within the masses after formation, and so some parts become much harder than others. Erosion from rain or from the sea is continually going on, and its action being greater in the softer than in the harder parts, we have a great variety of fantastic forms along the shore, and many caves underground.

It has long been supposed that there was a core of solid rock under the limestone, but only recently have any definite data been obtained in regard to it. Pirsson, 1914, gives the particulars in regard to a boring made in the hope, which was not fulfilled, of obtaining a supply of fresh water. The boring was in Southampton parish, about a mile west of Gibbs Hill Lighthouse, 135 feet above sea level. To 380 feet

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[1] For a summary of the results of investigations as to the parts taken in the formation of "coral" islands, by animal and vegetable organisms, see Howe, 1912.

below the surface it was the ordinary soft limestone; then to 695 feet, earthy, decomposed lava, in the lower part of the range with fragments of solid lava, sometimes waterworn; then to 1413 feet, the lowest point reached, solid lava. Considering these data in connection with our knowledge of the present under-water Bermuda, the slope from the present island to the ocean floor, the conclusion is reached that a great volcanic cone was formed, perhaps in the early Eocene, with its summit where the present island is, rising about 11,000 feet above the sea. The 718 feet above the bottom of the boring and an unknown distance below consist of the unchanged lava of the cone; the 315 feet layer above this was produced by the disintegration of the upper part of the cone; the foraminifera found in the 380 feet of limestone indicate that its formation, by the same processes that are now at work, began before the end of the Eocene; while the occurrence of the limestone 245 feet, and the decomposed lava 560 feet below sea level, indicate a long-continued subsidence.

At the present time there are no bodies of fresh water on the islands; rain water sinks almost immediately into the porous soil, which is also honeycombed by large and small caves and passages; brackish water can be obtained at sea level anywhere, but strictly fresh water nowhere. A curious instance of this permeability was told us by Mr. Reid Trott, owner of the aquarium known as the Devil's Hole; this is on the shore of Harrington Sound, distant a quarter of a mile, rather high ground, from the south shore; in a southerly storm the surf is very heavy on the south shore, and white from the fine lime of the beaches; within a day or two the water in the aquarium becomes milky. The only visible outlet of Harrington Sound is by the narrow passage at Flatts Bridge; but though the rise and fall of the tide in the Sound is only a few inches, it has been calculated that it represents a flow through unseen passages of much more than passes under the bridge. Devonshire Marsh forms a sort of bowl, with higher ground on all sides; surface drainage into this fills the ditches with practically pure fresh water after rains, but it soon disappears, and only a few species of fresh water algae are able to avail themselves of the short opportunity.[2]

A few species of "Fucus" are mentioned by Turner, Icones Fucorum, 1808–1819, but actually our knowledge of the algae of Bermuda

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[2] A * is placed before the name of each fresh water or terrestrial species listed, including some Myxophyceae found here within range of tides, though not normally marine.

begins with the list published in the Canadian Naturalist by the Rev. Alexander F. Kemp (Kemp, 1857), who visited the islands in 1856 and collected somewhat extensively. Sixteen years later J. J. Rein, who had been a tutor in an English family at Bermuda, published two papers on the vegetation of the islands, one of them with a list of the algae (Rein, 1873). In 1881 Prof. W. G. Farlow made quite extensive collections, and some of the material obtained was distributed in the set of exsiccatae, Farlow, Anderson & Eaton, Algae Exsiccatae Boreali-Americanae. At a later visit, in 1900, Farlow collected additional species, a few of which were distributed in Collins, Holden & Setchell, Phycotheca Boreali-Americana, but otherwise no publication has been made of the material collected by him. The Challenger Expedition visited Bermuda, and the results are given in a preliminary paper (Dickie, 1874) and in a volume of the Results of the Challenger Expedition. In these are included the species listed by Kemp and Rein and those distributed by Farlow, with comparatively few additions. In the Journal of Botany George Murray published a Catalogue of West Indian marine algae (Murray, 1889), including in it the Bermuda lists above mentioned; noting that Bermuda did not belong to the West Indies, geographically or politically, but might be considered as having a similar flora. Setchell, 1912, is a paper calling attention to several species in the Farlow herbarium. Longer or shorter lists of algae occur in local publications, traveller's guides etc., but based on the papers above noted, and adding nothing to what is found in them. Occasional references to Bermuda occur in general works, but only as citations from the works mentioned, or referring to some specimen collected by Farlow.

Through the kindness of Mrs. Jane A. Sutherland, daughter of Mr. Kemp, we have been able to examine his collection, which still includes nearly all the species listed by him. Professor M. Möbius very kindly sent us for examination the Rein algae, now preserved in the collection of the Senckenbergischer Gesellschaft at Frankfurt a/m.; by the favor of Dr. D. Prain, Director of the Royal Botanic Gardens, Kew, we have examined specimens of the species added by the Challenger expedition; and Professor Farlow has given every facility for the study of his rich material, including beside his own collecting, specimens collected by G. Tucker in 1856 and Walter Faxon in 1882. In the collection of one of the writers is a considerable number of algae collected in 1890 by W. S. Wadsworth.[3] Miss Wilkinson of Ripleigh,

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[3] A similar set is in the herbarium of the University of California.

Hamilton, has kindly allowed us to refer to an interesting collection she has made, and we are also much indebted to her for information as to stations of some of the rare species. In 1882 Miss Kate Peniston, now Mrs. Matthews, sent one of us some algae from the Harrington Sound region; comparatively few specimens, but including some of much interest. Several species from Bermuda are recorded by Dr. M. A. Howe in his papers in the Bulletin of the Torrey Botanical Club, and some of them have been distributed in the Phycotheca Boreali-Americana. An occasional specimen from some other collector will be noted in its appropriate place. Collections were made by ourselves in the years from 1911 to 1917, during which period one or the other of us has been in Bermuda rather more than half of the time, collecting in practically all parts of the islands and in all months except June. While future additions are of course to be expected, we think that the main characters of the algal flora are fairly settled, and the greater part of the species determined. A special effort has been made to distribute in the Phycotheca Boreali-Americana as full a representation as possible of Bermuda algae, and fascicles XXXVIII, XXXIX, XLI, XLII and XLIV consist entirely of specimens from the islands.[4] We have distributed in this way every species of which sufficient material was available.

A number of new species are described and figured in the following pages, and we have tried to give all details of value in regard to them. In case of other species, whenever we could add anything to previous knowledge of them, we have tried to do so, but no full descriptions have been given except for new species, varieties etc. Concise keys however, have been furnished, and we think will prove useful. We have been rather full in notes as to character of station, as this is something sadly lacking in many floras. Exact localities have been given, for the aid of future students, and the date of collecting is given by month, but it has not seemed necessary to give the year. No full synonymy is given, but pains have been taken to give for each species the proper name under the international rules; the original name, if published under another genus; and when possible reference to a good figure. Whenever specimens from Bermuda have been distributed in the Alg. Am.-Bor. Exsicc. or in the P. B.-A., reference is given by number. Other references are given in cases

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[4] A set of these fascicles will be found at the Bermuda Agricultural Station, to whose Director, Mr. E. J. Wortley, we are indebted for many kindnesses during our visits to the islands.

where it seemed desirable, especially from distinctively American works, like Harvey, Nereis Boreali-Americana and Börgesen, The Marine Algae of the Danish West Indies. The latter is specially useful in connection with the present work, being a careful study of the marine flora of a small group of islands, of character not unlike Bermuda, though somewhat farther south. As Börgesen's work is still incomplete as this paper goes to press, full comparisons are not yet possible.

We had hoped to publish with the present paper somewhat full comparisons of the floras of Bermuda and other regions, but the list for the Danish West Indies, perhaps the most instructive, is not fully available. We have reluctantly had to omit from our list the families Rhizophyllidaceae, Squamariaceae and Corallinaceae; without careful study of the types any conclusions in these critical families would be uncertain, and in the present European conditions such study has not been practicable. In view of this we have made only a short statement, by classes, showing the percentage of the Bermuda species common to nine of the best known regions where a similarity might be expected. If later we are in position to take up the families now omitted, and a full account of the algae of the Danish West Indies is available, the proposed full comparison may be made. In the present comparison we have not included the Class Myxophyceae; first because the species of this class are largely cosmopolitan, second because in many regions where the other classes are fairly well known, the Myxophyceae have been little studied. We have considered a species as common to two regions, though represented by different forms or varieties in each; pelagic species, known only as washed ashore, have not been included.

Percentage of Bermuda algae represented in other floras.

	Chlorophyceae	Phaeophyceae	Rhodophyceae	Total
Great Britain	28	34	26	27
N. and NW. France	24	30	26	25
Bay of Biscay	11	20	25	18
Mediterranean	29	34	33	31
Canaries	19	28	23	21
New England	22	24	16	19
Florida	32	43	44	40
Jamaica	38	63	32	41
Barbados	33	41	32	33

The nine regions used in the above comparison are not equally well known; the affinity to an intensively studied region like Great Britain is somewhat overstated, that to a less thoroughly studied region, like the Canaries, understated; but some general indications may be obtained. Perhaps the most striking is the distinctness of the Bermuda flora, having only 41 per cent in common with Jamaica, and not so much in common with any of the others. Taking the three classes represented, there is only one in which more than half the species are common to another region, again Jamaica, which has 63 per cent of the Bermuda brown algae. Taking all the regions, the similarity is greatest in the brown algae, least in the green. The affinities of the Bermuda flora are evidently strongest with the Florida-West India region, next with the Mediterranean, and after that with more northern localities. New England has probably the least in common with Bermuda of all the regions compared, its slight numerical superiority over the Canaries being probably due to the less thorough exploration of the latter.

The following list of important stations, with indication of the characters of each, will, we think, be of use to future collectors; in a region where the coast line is so long in proportion to the surface area, many such stations must exist, but we think we have listed the more important ones.

In this list of stations we aim to conduct our readers around the whole island and point out the places where we have found certain forms of algae most common. Driven in on all sides by the winds one will find abundance of *Sargassum natans* "gulfweed" of which the farmers make so profitable use as a fertilizer. This grows in mid-ocean and is never found attached to the shores. Other species of the same genus are found growing all about the island along with other litoral plants. Many other forms such as *Ulva, Bryopsis, Caulerpa, Codium, Laurencia, Dictyota, Padina, Spyridia* etc. will be found almost everywhere, and so will not require special mention. We will start from Hamilton, going west to Fairyland and Grasmere; there we shall find shallow water and abundance of plants. Breaking into the land opposite Agar's Island is a large bay; as we first come to it on our left we shall find a large growth of mangrove trees among the roots of which in shallow water we will find abundance of the endemic *Halymenia bermudensis,* the loose, small form. Farther along in front of a cottage is rich collecting ground; another of the new plants, *Chondria curvilineata* occurs here, and very large masses of *Valonia macrophysa;* a larger form of the *Halymenia* was gathered in abundance in a little bay that comes up in front of the Grasmere Hotel. Beyond the hotel is a water called Mangrove Creek, lying between the hotel and Spanish Point, where good collecting may be had. At the extreme end of Spanish Point are two little bays, the larger of which is called Stovel Bay; this furnished good specimens of *Dudresnaya crassa* and Liagoras in the spring. It is well to make a careful search all about Spanish Point as far east as the Admiralty House. Beyond that as far as the Ducking Stool the shore is for the most part high and precipitous, and we did not find much to reward the climb down and up; but coming in a boat one finds a fairly rich flora, *Liagora* etc., at the base of the cliffs.

From the Ducking Stool to the Inlet of Harrington Sound most of the collecting was of the smaller forms, some of them microscopic. At one point, perhaps half a mile from the Inlet, was found at one time an abundance of *Coelarthrum Albertisii*, as it was also on the outer point of the Gibbet Islands. These two islands and the little beaches on either side, being near our place of abode, were carefully studied, and yielded from time to time several interesting things, among them the new *Lophosiphonia Saccorhiza*, growing on a *Codium; Halymenia Agardhii* and *Antithamnion cruciatum* var. *radicans* also occurred here. The Inlet of Harrington Sound is good collecting ground for several species; on the south side is plenty of *Ceramium nitens*, and on the wall of the Frascati Hotel may be found at all times a fine growth of *Callithamnion Halliae; Heterospora Vidovichii* also grew on this wall, and *Avrainvillea nigricans* grows buried in the mud in the lower part of the Inlet. Over on the north side in the shallow water one may find abundance of *Udotea* and *Penicillus*. Within the Sound near the bridge is always an abundance of *Wrangelia penicillata*, and always also *Griffithsia tenuis;* in Tucker's Bay at the west end of the Sound we first found *Neomeris annulata*, afterwards found at several other stations; farther to the north, in Major's Bay, were two or three species of *Bryopsis*. At the farther end of the Sound in a little cove near Walsingham House, called Dingle Bay, we found rich collecting; it is the best station for characteristic *Hypnea musciformis* and for *Champia parvula*, rare in Bermuda, and the only station for the new *Dasya spinuligera*, also the original station for *Nitophyllum Wilkinsoniae;* on the south side of the Sound we found our best growth of *Acetabularia crenulata* in a little pool near the chapel; the species is common in many other places, however; the shores of the Sound everywhere abound in species of *Bryopsis* and *Laurencia*.

About a mile north of Flatts Village we come to Shelly Bay, a fine beach; here in its season may be found the new *Chondria polyrhiza*, and at the north end of the Bay is a fine growth of *Udotea flabellum;* half a mile beyond Shelly Bay is Burchell Cove, well worth a visit; here we found splendid specimens of *Callithamnion Halliae.* Bailey's Bay, something over a mile beyond, is a good place for collecting; here we found some of our best specimens of *Eucheuma denticulatum.* In going on towards St. George's it would be worth while to take the old and now unused road about a quarter of a mile beyond Bailey's Bay, and follow along the shore to the old ferry, and then past Joyce's Caves to the Causeway. At the north end of the Causeway we come to Long Bird Island,[5] on the southeast side of which all the way to the Swing Bridge is good collecting, especially of *Helminthocladia Calvadosii* and *Castagnea.*

Beyond Swing Bridge the road winds with many a picturesque turn along the shores of Mullet Bay into St. George's; these waters ought to be fertile grounds for they are for the most part shallow and easily accessible. Once in St. George's we are in the immediate neighborhood of some of the best collecting grounds in Bermuda; going to the shore northwest of the city we first come to Tobacco Bay which is in fact two quite distinct bays near together; plenty of *Bryopsis* and *Liagora* here. A little farther along very near the old fort at St. Catherine's Point, where the shore makes a right angled turn to the east, is a little bay called Achilles Bay, where *Helminthocladia* may be found in abundance in its season. Following the shore for a mile to the east we pass several little coves which may be worth a visit; but just before we come to the place where the sewer from the hospital comes down, we come to Judy's Hole, so called in honor of a colored woman whose body was washed ashore here. Here we found splendid specimens of *Wrightiella Blodgettii* and *Naccaria corymbosa* floating in on the breakers. Farther along is Sylvester's Bay and beyond that Buildings Bay, so named from the fact that here Sir George Summers built the little ships in which he sailed away for Virginia. It is a little cove extending in behind an old fortification; there is a little beach at the head of the bay; comparatively few plants grow on the rocks along the shore or on the bottom, but among them is the

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[5] This is the "Oblongarum Avium Insula" of the map in Jansen's atlas, Vol. III, 1646. This map, a copy of the original survey of 1622, is remarkably full and accurate; names of places have hardly changed at all, and the family names of many of the owners there given appear today everywhere in the islands. This accuracy and fullness is the more remarkable in contrast with the maps in the same volume, covering the mainland from Labrador to Florida; contours are vague and uncertain, and names strangely transposed.

"Staghorn" *Codium*, the very large form of *C. decorticatum*. But many things that come in there on the tide show that there are very fertile grounds outside; there is *Dudresnaya crassa, Trichogloea Herveyi, Naccaria corymbosa, Dasya pedicellata* and several other Dasyas, *Crouania attenuata*, Callithamnions, Liagoras etc.; there are probably more things to be found here than in any other like place in Bermuda. Just beyond this is Gates Bay, noted for abundance of *Crouania, Liagora* and *Laurencia*, for the most part epiphytic on *Sargassum*.

On the harbor side of St. George's may be found some good collecting; here by an old wharf at the eastern end of the city we found *Antithamnion cruciatum* and our only specimens of *Caulerpa verticillata*. Taking the ferry to St. David's and crossing over to the south side of the island near the lighthouse we come to a beach where we found a fine growth of *Gracilaria dichotomo-flabellata* and some small specimens of *Eucheuma Gelidium*. At the west end of the Causeway we find a new road leading around the shore to Walsingham House; there is good collecting all along here; first of all at the left, a growth of mangrove trees, on the amphibious roots of which is abundance of three species of *Bostrychia*, mingled with *Caloglossa Leprieurii* and *Catenella pinnata;* these plants grow on such roots, as well as on rocks covered only at high tide, in every part of the island. There are two little tide pools in the immediate vicinity of Moore's calabash tree in one of which are two or three species of *Caulerpa* and *Udotea flabellum;* in the other, smaller, one, partly under a big rock, the bottom is carpeted with delicate fronds of *Caulerpa sertularioides;* in the neighborhood of Walsingham House are several little coves rich in plants; one a hundred yards or so to the right of the driveway leading up to the main road always contains *Chrysymenia uvaria* in fine form; here also in 1915 we found a splendid growth of *Halymenia pseudofloresia*, and it is the only place in which we found more than a single frond or a fragment. Over on the shore of Castle Harbor in April we found a good collection of *Spyridia aculeata* var. *hypnoides*.

Following the southwest shore of Castle Harbor for a mile and a half we come to Tucker's Town, another fruitful locality; here in a little grotto, back of the concrete wharf, growing at all seasons are *Halymenia bermudensis* and *Galaxaura obtusata;* on the shore in front of the wharf where a small stream runs into the sea are quantities of *Gelidium pusillum* and around the point to the left a heavy growth of *Eucheuma denticulatum;* all about the wharf are fronds of *Ulva*, yards long. A boat can be taken from Tucker's Town to Cooper's Island, famous as a rich station; here in a single day in 1881 Farlow found *Dudresnaya caribaea, D. bermudensis, Calosiphonia verticillifera* and *Kallymenia perforata,* none of which except the second have been found in Bermuda since; we have made several visits to the island in the hope of finding them, but in vain, but each trip was rewarded by unexpected good things.

From Tucker's Town way along the South Shore to Ely's Harbor, a distance of some fifteen miles, the shore presents an alternation of long beaches and high precipitous rocks, with but here and there a bay where one can collect algae. The reef runs along parallel to the shore, from a quarter to a half a mile outside. There are two or three little bays in Southampton which we have not explored; but we have found that the flora of the west end of the island is not nearly as rich as that of the east end. On the south shore east of the meridian of Hamilton are a few bays that should be mentioned; these are in the neighborhood of Devil's Hole, viz., Pink Bay, Smith's Bay and Gravelly Bay; a reference to the text will show what plants have been collected in these localities; special attention is called only to the last of the three, Gravelly Bay. It is not more than a quarter of a mile across the island from Devil's Hole; it has proved a remarkably fertile place; it is the only station where we have found *Gracilaria horizontalis, Turbinaria tricostata* and *Dilophus guineensis,* though the latter was found by Farlow in Paget. The place is rich in several species of *Dictyota,* also in *Zonaria lobata* and *Dictyopteris Justii* in their seasons. Here also we first found *Trichogloea Herveyi,* and we have found it there every season since; a little cave near the bay has yielded a number of species, rarely found elsewhere.

About a mile farther along towards the west we come to what is known as Spanish Rock; here at the foot of a high precipice, *Colpomenia sinuosa* and *Hydroclathrus cancellatus* cover the rocks, and may be collected at low tide; another mile along in the same direction we come to Harris Bay, another good station; here several species of *Spyridia* and *Liagora* abound, also two species of *Sphacelaria, Wrightiella Blodgettii, Digenea simplex* and others; it is the only station for *Udotea conglutinata* and *Rosenvingia intricata.* Devonshire Bay just beyond we did not find very productive, but a mile and a half farther on is Hungry Bay, which will reward several visits at different seasons; Dictyotas and Dictyopteris abound here in summer, and in the tidal creek Howe collected *Acicularia Schenckii,* the only time it has been found in Bermuda; in this creek also is excellent *Ernodesmis verticillata. Geminella scalariformis* forma *marina* was found in a pool in the rocks on the west side of the bay.

Ely's Harbor and Mangrove Bay towards the west end of the group are noted for nothing in particular, but are by no means barren; in the former we found a better growth of *Porphyra atropurpurea* than elsewhere. Now crossing the land to the shore on the inside of the great hook that this end of the group makes, and going along to the neighborhood of Gibbs Hill light, we come to Jew's Bay and Heron Bay, in both of which good collecting may be had, especially in the latter, with its shallow still water and sunny exposure; we found it very fertile with several species of *Gracilaria, Laurencia, Spyridia, Chondria curvilineata* and other things. Coming back to Hamilton we may find something at Salt Kettle. The wall of the quay at Hamilton below low tide is well covered with algae, and a big timber float lying there yielded a rich harvest of *Polysiphonia foetidissima.* This brings us round to the point of beginning.

Class **MYXOPHYCEAE.**

Family CHROOCOCCACEAE.

Chroococcus Nägeli.

1. Cells 3–8 μ diam.,	1. C. membraninus.
1. Cells 13–25 μ diam.	2. C. turgidus.

*1. C membraninus (Menegh.) Nägeli, 1849, p. 46; P. B.-A., No. 2151; *Pleurococcus membraninus* Meneghini, 1842, p. 34, Pl. IV, fig. 1. In brackish pool near race course, Aug.; in ditch in South Shore marshes, Sept., Collins. In the material from the locality first named the cells were dividing rapidly, and average smaller than in P. B.-A., No. 1201, about like Wittrock, Nordstedt & Lagerheim, No. 1538. Sometimes the division of the cells goes on so much faster than the separation of families that a mass resembling a *Microcystis* is formed.

2. C. turgidus (Kütz.) Nägeli, 1849, p. 46; *Protococcus turgidus* Kützing, 1845–49, p. 5, Pl. VI, fig. 1. In gelatinous masses in brackish pools, and in films on decaying algae near Flatts Bridge, April, Collins.

Synechocystis Sauvageau.

* S. aquatilis Sauvageau, 1892a, p. CXVI. On rocks near Hungry Bay, April; in cave, Agar's Island, Aug., Collins.

Synechococcus Nägeli.

* S. aeruginosus Nägeli, 1849, p. 56, Pl. I. E, fig. 1. Among other algae in brackish pool near race-course, Aug., Collins. Cells about 14 × 7 μ, which is rather small for this species.

Chroothece Hansgirg.

1. Cells seldom under 20 μ diam.	1. C. Richteriana.
1. Cells not over 3 μ diam.	2. C. cryptarum.

1. C. Richteriana forma marina Hansgirg, 1889, p. 5; P. B.-A., No. 702. Farlow; rather common on shaded stone work and on sides of caves, Collins.

2. C. CRYPTARUM Farlow in P. B.-A., No. 752; Forti, 1907, p. 30. Farlow; on walls and roofs of caves, often in company with *C. Richteriana. Gloeothece rupestris* often occurs in company with these two species, the whole forming a continuous stratum, generally one or two mm. thick, extending from just above low water mark to much above high water mark. Between tide marks it is a rich green and gelatinous, but beyond the range of tides it is yellowish or whitish and crumbly.

GLOEOCAPSA Kützing.

1. Cell without wall, 1.5–2 μ diam.; tegument yellow or brown. 1. G. fusco-lutea.
1. Cell without wall, over 2 μ diam.; tegument colorless or nearly so. 2.
  2. Colony amorphous, soft; cell without wall, 2–5 μ diam. 2. G. montana.
  2. Colony subspherical, firm; cell without wall, 4–6 μ diam. 3. G. atrata.

*1. G. FUSCO-LUTEA (Näg.) Kützing, 1849, p. 224; P. B.-A., No. 2153. *G. ambigua* var. *fusco-lutea* Nägeli, 1849, p. 50. On rocks, Hungry Bay, in company with *Synechocystis aquatilis,* April, Collins. The color of the tegument varies from dark brown to pale yellow.

*2. G. MONTANA Kützing, 1843, p. 173; 1845–49, p. 14, Pl. XIX, fig. 2. On wall of cave near Causeway, high up, April, Collins.

*3. G. ATRATA (Turp.) Kützing, 1843, p. 174, Pl. VI, fig. 1; *Globulina atrata* Turpin, 1830, Pl. V, fig. 6. On cliff, away from the sea, in company with *Scytonema* etc., Aug., Collins. The colonies are usually quite regularly spherical; they range from about 30 μ diam., containing only two cells, to above 140 μ diam., with hundreds of cells. The contents is bright green, somewhat granular; the surface inside the wall is usually thickly set with very short, bristle-like projections; bacterial?

GLOEOTHECE Nägeli.

1. Cell without tegument, about 2 μ wide. 1. G. confluens.
1. Cell without tegument, about 5 μ wide. 2. G. rupestris.

*1. G. CONFLUENS Nägeli, 1849, p. 58, Pl. I. G, fig. 1. On wall of shallow cave, by inland road, April, Collins.

*2. G. RUPESTRIS (Lyng.) Bornet in W. & N., No. 399, 1880; *Palmella rupestris* Lyngbye, 1819, p. 207, Pl. LXIX, fig. D; *G. membranacea* Bornet, 1892, p. 175. Common all about the islands in clefts of rocks, rock pools, roadsides, within reach of salt water or far from it. As noted by Bornet, 1892, p. 175, it varies much in the appearance of the stratum, from thick gelatinous masses to thin films, also in the development of the concentric walls; in a rock pool of fresh water, near the Old Ferry road, we collected a form quite without these walls, closely resembling *Aphanothece microscopica,* P. B.-A., No. 552; but it seems probable that it is merely a state of the present species corresponding to Bornet's section I, in which he includes *Microcystis microspora* Menegh. This form distributed as P. B.-A., No. 2154. Lyngbye's specific name, used by Bornet in 1880, is the oldest, and must supersede the name used by Bornet in 1892.

Entophysalis Kützing.

E. granulosa Kützing, 1843, p. 177, Pl. XVIII, fig. 5; Bornet & Thuret, 1876, Pl. I, figs. 4 & 5. On rocks, North Shore, Aug., Collins.

Microcystis Kützing.

* M. marginata (Menegh.) Kützing, 1845–49, p. 6, Pl. VIII; *Anacystis marginata* Meneghini, 1836, p. 6; 1842, p. 93, Pl. XIII, fig. 1. With other algae on wall of cave near Causeway, April, Collins.

Merismopedium Meyen.

1. Families 50–150 μ square. 1. M. glaucum.
1. Families 1–4 mm. square. 2. M. convolutum.

*1. M. glaucum (Ehrb.) Nägeli, 1849, p. 55, Pl. I. D, fig. 1; *Gonium glaucum* Ehrenberg, 1838, p. 56, Pl. III, fig. 5. Among other algae in pool by race course, Aug., Collins.

*2. M. convolutum Brébisson in Kützing, 1849, p. 472; 1855, p. 13, Pl. XXXVIII, fig. IX. Among various algae in Harrington Sound; in cave at Gravelly Bay, Jan., Hervey.

Oncobyrsa Agardh.

O. marina (Grun.) Rabenhorst, 1865, p. 68; *Hydrococcus marinus* Grunow, 1861, p. 420. On *Dictyopteris Justii,* Gravelly Bay, Aug., Collins; on *Sphacelaria,* Spanish Rock, March, Hervey.

CHLOROGLOEA Wille.

C. TUBERCULOSA (Hansg.) Wille, 1900, p. 5, Pl. I, figs. 1–6; *Palmella ? tuberculosa* Hansgirg, 1892, p. 240, Pl. VI, fig. 9. On *Bostrychia, Catenella* etc., in company with other minute Myxophyceae.

FAMILY CHAMAESIPHONACEAE.

PLEUROCAPSA Thuret.

P. CONFERTA (Kütz.) Setchell, 1912, p. 229; *Palmella conferta* Kützing, 1845, p. 149; 1845–1849, p. 12, Pl. XVI, fig. IV. On *Rhodochorton speluncarum*, in cave, Agar's Island, Aug.; on *Gelidium pusillum*, Harrington Sound, April, Collins.

HYELLA Bornet & Flahault.

H. CAESPITOSA Bornet & Flahault, 1888a, p. 162; 1889, p. CLXV, Pl. X, figs. 7–8, Pl. XI. In dead shells, in company with *Gomontia, Mastigocoleus* and *Plectonema*, but usually the least abundant of the four.

DERMOCARPA Crouan.

1.	Cells scattered.	1. D. solitaria.
1.	Cells laterally united in pulvinate expansions.	2. D. prasina.

1. **D. solitaria** sp. nov.; P. B.-A., No. 2155. Cellula solitaria, clavata, circa 8 μ diam., supra discum basale paullo majus; superne uniformiter incrassata, vel interdum prope basin parvam expansionem annulatam ferente, usque ad apicem rotundatam, circa 20 μ diam.; longitudine ad 75 μ; ad maturitatem in duas cellulas divisa, superiore in gonidangium subsphaericum mutanda, gonidia pro more 8–12, 5–6 μ diam., continente; cellula inferiore obconica, supra plana vel concava, contentu laete aeruginoso; membrana crassa, sublamellosa.

Cell solitary, clavate, about 8 μ diam. above the slightly larger basal disk, increasing in diameter upwards uniformly, or sometimes with a slight ring-like expansion near the base, to the rounded apex, about 20 μ diam.; height up to 75 μ. At maturity dividing into two cells, the upper a subspherical gonidangium, containing gonidia, 5–6 μ diam., usually 8–12 in number; the lower cell obconical with flat or concave upper surface, contents bright blue-green; wall thick, somewhat lamellate.

On older parts of fronds of *Spermothamnion gorgoneum* and *Ceramothamnion Codii*, which grew on *Codium decorticatum*, in company with *Xenococcus Schousboei*, *Lyngbya Meneghiniana* and other small algae. The cells are always scattered, never forming cushion-like masses, as is the case with most species of *Dermocarpa*. The general appearance of the plant is not unlike that of some small species of *Codiolum*, except for the shade of color, and that the colorless stipe is shorter.

2. D. PRASINA (Reinsch) Bornet & Thuret, 1876, p. 75, Pl. XXVI; P. B.-A., No. 2051. *Sphaenosiphon prasinus* Reinsch, 1875, p. 73, Pl. XII. Not *D. prasina* P. B. A., No. 1, which is *D. Farlowii* Börgs. On *Catenella Opuntia* var. *pinnata* generally.

XENOCOCCUS Thuret.

X. SCHOUSBOEI Thuret in Bornet & Thuret, 1880, p. 74, Pl. XXVI, figs. 1–2; P. B.-A., No. 2052. On *Lyngbya confervoides*, in ditch back of Shelly Bay, Aug., Collins. Cells mostly separate and exactly spherical; but sometimes closely packed and compressed.

Var. PALLIDA Hansgirg, 1889, p. 5. On algae on roof of cave, Gravelly Bay, April, Collins. What may be a species of *Xenococcus* with minute cells was found on *Oedogonium* from Devonshire marshes, but could not be specifically identified.

FAMILY OSCILLATORIACEAE.

SPIRULINA Turpin.

1. Trichome rose-color.	1. S. rosea.
1. Trichome aeruginous.	2.
2. Trichome less than 1 μ diam., spiral loose.	2. S. tenerrima.
2. Trichome over 1 μ diam., spiral close.	3. S. subsalsa f. oceanica.

1. S. ROSEA Crouan ex Gomont, 1893, p. 273. Forming a pinkish film on *Amphiroa* between tide marks, North Shore, Sept., Collins.

*2. S. TENERRIMA Kützing ex Gomont, 1893, p. 272; Kützing, 1845–49, p. 25, Pl. XXXVII, fig. I; P. B.-A., No. 2054. Among other algae in a coating on rock between tide marks, North Shore, Sept., Collins.

3. S. SUBSALSA forma OCEANICA Gomont, 1893, p. 274; P. B.-A., No. 2053. Among other algae at various stations.

OSCILLATORIA Vaucher.

1. Filaments torulose.	2.
1. Filaments not torulose.	6.
2. Trichomes 18–36 μ diam., loosely spiral.	1. O. Bonnemaisonii.
2. Trichomes not spiral.	3.
3. Trichomes and stratum dull red.	2. O. miniata.
3. Trichomes and stratum not red.	4.
4. Limicolous; trichomes 17–29 μ diam.	3. O. margaritifera.
4. Trichomes 6–11 μ diam.	5.
5. Limicolous or saxicolous; black-olive.	4. O. nigro-viridis.
5. Epiphytic; aeruginous, light green or light brown.	5. O. Corallinae.
6. Trichomes not attenuate at tip.	7.
6. Trichomes attenuate at tip.	8.
7. Trichomes 4–10 μ diam.	6. O. tenuis.
7. Trichomes less than 3 μ diam.	7. O. amphibia.
8. Apical cell capitate.	8. O. amoena
8. Apical cell not capitate.	9.
9. Trichomes 3 μ diam. or more.	10.
9. Trichomes less than 3 μ diam.	11. O. longearticulata.
10. Distinctly marine.	9. O. laetevirens.
10. Plant of fresh water pools.	10. O. formosa.

1. O. BONNEMAISONII Crouan ex Gomont, 1893, p. 235, Pl. VI, figs. 17–18; P. B.-A., No. 2055. Forming floating masses in ditch in Pembroke Marsh, Aug., Collins.

2. O. MINIATA Hauck ex Gomont, 1893, p. 236; P. B.-A., No. 2156. Hungry Bay, April, May, Collins. Forming a deep red film on the bottom, also floating clots adhering to everything. The filaments are usually about 20 μ diam., but occasionally as high as 45 μ. The plant decays very quickly, and even when put on paper with a promptness ample for most Oscillatorias, the coloring matter stains the paper purple, and the filaments remain nearly colorless.

3. O. MARGARITIFERA Kützing ex Gomont, 1893, p. 236, Pl. VI, fig. 19. In brackish pool with other algae, April, Sept., Collins.

4. O. NIGRO-VIRIDIS Thwaites ex Gomont, 1893, p. 237, Pl. VI, fig. 20. On rocks wet by salt water, Jan., Farlow.

5. O. Corallinae Gomont, 1893, p. 238, Pl. VI, fig. 21. On *Codium tomentosum*, Cooper's Island, April, Collins.

*6. O. tenuis Ag. var. tergestina Rabenhorst ex Gomont, 1893, p. 241. Among other algae in a ditch in meadow by Shelly Bay, Aug., Collins.

*7. O. amphibia Gomont, 1893, p. 241, Pl. VII, figs. 4–5; P. B.-A., No. 1852. In brackish pool among other algae, April, Aug., Collins.

*8. O. amoena Gomont, 1893, p. 245, Pl. VII, fig. 9. Forming a thin coating on rock at Inlet, Aug., Collins.

*9. O. laetevirens Crouan ex Gomont, 1893, p. 246, Pl. VII, fig. 11. Among other algae, Tucker's Town, May, Collins.

*10. O. formosa Bory ex Gomont, 1893, p. 250, Pl. VII, fig. 16. In a puddle of rain water in road, April, Collins.

11. O. longearticulata Hansgirg ex Forti, 1907, p. 176. On *Codium*, near Causeway, April, Hervey. We have not seen an authentic specimen of this species, but our plant agrees with the original description, with no description in Gomont, and with none but this in Forti.

Trichodesmium Ehrenberg.

T. Thiebautii Gomont, 1893, p. 217, Pl. VI, figs. 2–4; Wille, 1904, p. 57, Pl. I, figs. 17–22. Hamilton Harbor, Wille, l. c.[6]

Phormidium Kützing.

1. Trichomes strongly moniliform.	1. P. fragile.
1. Trichomes not moniliform.	2.
2. Stratum purple or pink.	2. P. luridum.
2. Stratum greenish or blackish.	3.
3. Trichomes 3 μ diam. or less.	3. P. valderianum.
3. Trichomes 4–12 μ diam.	4. P. Retzii.

1. P. fragile Gomont, 1893, p. 183, Pl. IV, figs. 13–15. Among other algae in an incrustation in rock between tide marks, April, Collins.

*2. P. luridum Gomont, 1893, p. 185, Pl. IV, figs. 17–18; P. B.-A.,

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[6] *Catagnymene pelagica* Lemmermann var. *major* Wille, 1904, p. 51, pl. I, fig. 7, is reported by Tilden, 1910, p. 159, as occurring at Bermuda, but we are unable to obtain any confirmatory evidence. Wille, l. c., reports it from open sea, at several points. *Dermocarpa Leibleinii* (Reinsch) Bornet var. *pelagica* Wille, also appears in Tilden, 1910, p. 55, as from Bermuda, on authority of Wille, 1904, p. 50; but Wille's record is 39° 4′ N., Long. 57° 8′ W., "ungefahr in der Mitte zwischen den Bermuda-Inseln und New Foundland."

No. 2056. Forming a pinkish film over rocks between tide marks, North Shore, Aug., Collins.

*3. P. VALDERIANUM Gomont, 1893, p. 187, Pl. IV, fig. 20; P. B.-A., No. 2157. Among other algae in a blackish coating on rocks and on *Bostrychia*, Aug. In thick wrinkled sheets on brackish water, near old race course Dec. Collins.

*4. P. RETZII Gomont, 1893, p. 195, Pl. V, figs. 6–9; P. B.-A., No. 2057. Forming a light green, firm coating on rock between tide marks, North Shore, Sept., Collins.

LYNGBYA Agardh.

1. Filaments attached at the middle. 1. L. Meneghiniana.
1. Filaments attached at one end or free. 2.
2. Trichomes over 5 μ diam., usually over 7 μ. 3.
2. Trichomes 4 μ diam. or less, seldom over 3 μ. 5.
3. Trichomes 16–60 μ diam., dissepiments not granulate. 2. L. majuscula.
3. Dissepiments granulate. 4.
4. Trichomes 9–25 μ diam., apex not attenuate nor capitate. 3. L. confervoides.
4. Trichomes 5–12 μ diam., apex usually attenuate and capitate. 4. L. semiplena.
5. Trichomes 2.5–4 μ diam., straight or flexuous, not regularly spiral. 5. L. lutea.
5. Trichomes about 2 μ diam., more or less spiral. 6. L. Lagerheimii.

1. L. MENEGHINIANA Gomont, 1893, p. 145. Mangrove Creek, Farlow; on Codium, Cooper's Island, Collins; Gibbet Island, March, Hervey. The only representative here of the subgenus *Leibleinia,* the filaments bent hairpin-shape, attached in the middle, both ends free.

2. L. MAJUSCULA Harvey ex Gomont, 1893, p. 151, Pl. III, figs. 3–4; Harvey, 1858, p. 101, Pl. XLVII. A; P. B.-A., No. 2001. Rein; Moseley; Walsingham Grotto, March, Alden Fish pond, Dec., Hervey. Usually blackish green, occasionally reddish or violet.

3. L. CONFERVOIDES Agardh ex Gomont, 1893, p. 156, Pl. III, figs. 5–6; including forma *violacea* Collins, P. B.-A., No. 1853. Common in floating masses in quiet waters, as attached tufts in more exposed places, nearly everywhere. A brownish or yellowish green is the more usual color, but violet and reddish shades are not uncommon. These are in striking contrast to the normal color, but from our observations on the species of *Lyngbya* found at Bermuda, we are

of the opinion that there is no justification for keeping color forms distinct taxonomically. Both colors occur in nature, both in dried material; plants originally aeruginous may change to red, plants originally red fade to pale green. We have no suggestion to make as to the causes determining these changes, except the general principle in regard to filamentous Nostocaceae, that red forms generally occur where the plant is always under water, not left exposed at low tide.

4. L. SEMIPLENA J. G. Agardh ex Gomont, 1893, p. 158, Pl. III, figs. 7–11. Not uncommon among other small algae; rarely pure.

5. LYNGBYA LUTEA Gomont, 1893, p. 161, Pl. III, figs. 12 & 13. Among various small algae, not found pure; bright red form on *Codium*, Harris Bay, Dec., Hervey.

*6. L. LAGERHEIMII Gomont, 1893, p. 167, Pl. IV, figs. 6–7. On decaying *Sargassum*, near Shelly Bay, April, Collins.

SYMPLOCA Kützing.

1. Cells 1–2 diam. long, aeruginous.	1. S. muscorum.
1. Cells much shorter than their diam., violet.	2. S. violacea.

*1. S. MUSCORUM Gomont, 1893, p. 130, Pl. II, fig. 9. On rock by roadside, Aug., Collins.

2. S. VIOLACEA Hauck ex Forti, 1907, p. 311; Hauck, 1885, p. 507, fig. 224. On ground near margin of pool in woods by Walsingham, April, Collins. This appears to have been overlooked by Gomont in his monograph either as an accepted species or among "species inquirendae" or "species excludendae." Hauck's record is included by Forti in the Sylloge, and by the international rules, which fix Gomont's monograph as the point of departure for homeocysted filamentous Nostochineae, 1907 is the date of publication. The Bermuda plant agrees with Hauck's description and figure; the violet color and short cells distinguish it from all other marine species.

PLECTONEMA Thuret.

*P. NOSTOCORUM Bornet ex Gomont, 1893, p. 122, Pl. I, fig. 11. Common in gelatinous masses of algae of various kinds.

PORPHYROSIPHON Kützing.

*P. NOTARISII Kützing ex Gomont, 1893, p. 69, Pl. XII, figs. 1–2. On *Juniperus bermudiana*, Aug., Collins.

MICROCOLEUS Desmazières.

1. Terrestrial. 3. M. vaginatus.
1. Marine. 2.
  2. Trichomes 2.5–6 μ diam. 1. M. chthonoplastes.
  2. Trichomes 1.5–2 μ diam. 2. M. tenerrimus.

1. M. CHTHONOPLASTES Thuret ex Gomont, 1893, p. 91, Pl. XIV, figs. 5–8; P. B.-A., No. 1854. Common among other small algae in incrustations on rocks, and on bottoms of shallow pools; occasionally nearly pure, as a thin, blackish coating; also in fresh water reservoir near Spanish Rock, Hervey.

2. M. TENERRIMUS Gomont, 1893, p. 93, Pl. XIV, figs. 9–11. Occasional filaments among *M. chthonoplastes*, less commonly among other small algae.

*3. M. VAGINATUS var. MONTICOLA Gomont, 1893, p. 94. On moist ground at roadside near Flatts Bridge, Dec., Hervey.

HYDROCOLEUM Kützing.

1. Trichomes 14–24 μ diam. 2.
1. Trichomes 8–14 μ diam., rarely to 16 μ; sheaths irregular, gelatinous, often quite diffluent. 2. H. lyngbyaceum.
  2. Color of mass of violet shade; sheaths cylindrical, distinct. 1. H. comoides.
  2. Color of mass dull green or yellowish; sheaths irregular, becoming shapeless and diffluent. 3. H. glutinosum.

1. H. COMOIDES Gomont, 1893, p. 73, Pl. XII, figs. 3–5. Farlow, fide Gomont, l. c.; on rocks, Hungry Bay, April, Collins.

2. H. LYNGBYACEUM Kützing ex Gomont, 1893, p. 75, Pl. XII, figs. 8–10; P. B.-A., No. 2058. Farlow, fide Gomont, l. c.; occasional in pools, Collins. The latter resembling var. *rupestre* Gomont, l. c.

3. H. GLUTINOSUM Gomont, 1893, p. 77. Rocks east of Elbow Bay, Dec., Collins, forming a thin, tubercular coating on rocks between tides.

SCHIZOTHRIX Kützing.

1. Among algae in pools; trichomes 2–3 μ diam. 1. S. vaginata.
1. On damp walls; trichomes 1–1.7 μ diam. 2. S. calcicola.

*1. S. VAGINATA Gomont, 1893, p. 40, Pl. VII, figs. 1–4. In a gelatinous mass with other algae, North Shore, Sept., Collins; Harrington Sound, Nov., Hervey.

*2. S. CALCICOLA Rabenhorst ex Gomont, 1893, p. 45, Pl. VIII, figs. 1–3; P. B.-A., No. 2158. On shaded wall of house near South Road, Dec., Collins.

FAMILY NOSTOCHACEAE.

ANABAENA Bory.

1. Spores ovoid, not contiguous to heterocysts. 1. A. variabilis.
1. Spores subcylindrical, contiguous to heterocysts. 2. A. torulosa.

*1. A. VARIABILIS Kützing ex Bornet & Flahault, 1888, p. 226, P. B.-A., No. 2059. *Sphaerozyga Thwaitesii* Harvey, 1846–51, Pl. CXIII. B. Brackish pool, April, Collins; in reservoir near Spanish Rock, Jan., Hervey. In the material from the latter station the filaments were sometimes straight, but oftener curved as in *A. flos-aquae* Bréb.; the spores were those of *A. variabilis.*

2. A. TORULOSA Lagerheim ex Bornet & Flahault, 1888, p. 236. Among other algae, North Shore, Aug., Collins.

Sterile filaments of an *Anabaena* or *Cylindrospermum* were found on ground wet by rain, near Flatts Bridge, Aug., Collins. The cells were about 4 μ diam., spherical, or just after division discoid.

HORMOTHAMNION Grunow.

H. convolutum sp. nov. Trichomatibus pallide aerugineis, interdum rubescentibus, parallelis, elongatis, 3–5 μ diam.; cellulis 1–4 diam. longis, cylindricis, nodis leviter constrictis; heterocystis ovoideis vel sphaericis, 8–10 μ diam.; sporis ?; fasciculis tenuibus, inter utriculis hospitis penetrantibus, curvatis.

Trichomes pale aerugineous, sometimes with a shade of red, parallel, long, 3–5 μ diam.; cells 1–4 diam. long, cylindrical, slightly constricted at the nodes; heterocysts ovoid to spherical, 8–10 μ diam.; spores ?; fascicles slender, winding among the utricles of the host. On *Codium tomentosum,* Cooper's Island, Aug. 29, 1913, F. S. Collins. Type in Collins herb., No. 7239.

More slender than the other species of the genus, the cells relatively longer. The cluster of filaments winds about among the utricles of the host, the continued growth of the two plants causing the endophyte to turn and twist very sharply.

Nostoc Vaucher.

*N. COMMUNE Vaucher ex Bornet & Flahault, 1888, p. 203; P. B.-A., No. 1901; *N. ciniflonum* Bornet & Thuret, 1880, p. 102, Pl. XXVIII, fig. 13. Common everywhere, especially on sandy soil; thin brittle skins in dry weather, expanded thickish soft masses in wet weather. No spores seen. Native name, "Devil's Tobacco."

Family SCYTONEMACEAE Kützing.

Microchaete Thuret.

M. VITIENSIS Askenasy ex Bornet & Flahault, 1887, p. 85. Scattered filaments on *Wrangelia penicillata,* Harris Bay, Jan., Hervey.

Scytonema Agardh.

1.	Sheaths not lamellate.	2.
1.	Sheaths lamellate.	3.
2.	Trichomes 5–7 μ diam.	1. S. varium.
2.	Trichomes 6–14 μ diam.	2. S. ocellatum.
3.	Branches usually geminate, free and divergent.	4.
3.	Branches frequently solitary, adherent at base.	5. S. crustaceum.
4.	Filaments 15–21 μ diam.; sheath thin at apex.	3. S. figuratum.
4.	Filaments 18–36 μ diam.; sheath thick throughout.	4. S. myochrous.

*1. S. VARIUM Kützing ex Bornet & Flahault, 1887, p. 97; Kützing, 1850–52, p. 6, Pl. XXIII, fig. II. High up on walls of a cave at Walsingham; shore of pool near Walsingham, April, Collins.

*2. S. OCELLATUM Lyngbye ex Bornet & Flahault, 1887, p. 95; P. B.-A., No. 711, on dunes, Paget, Farlow.

*3. S. FIGURATUM Agardh ex Bornet & Flahault, 1887, p. 101; *S. thermale* Kützing, 1850–52, p. 5, Pl. XVIII, fig. III. High up on wall of cave near Walsingham, April, Collins.

Bornet, 1889a, p. 155, shows that *Conferva mirabilis* Dillwyn, 1807, Pl. XCVI, is identical with *Scytonema figuratum* of Agardh, and of earlier date, and therefore changes the name to *S. mirabile* (Dillw.) Bornet. But as the starting point for nomenclature of the heterocysted Nostochaceae is definitely fixed at the Bornet & Flahault monograph, it appears as if the later name by Bornet cannot be substituted.

*4. S. myochrous Agardh ex Bornet & Flahault, 1887, p. 104; Kützing, 1850–52, p. 7, Pl. XXV, fig. III; P. B.-A., No. 1902. On perpendicular cliff, Paget, Aug., Collins; and common in company with *Calothrix* species etc. on rocks between tides. This species has a very wide distribution as a plant of rocks etc., dripping with fresh water, but in Bermuda it is commonly found with distinctly marine species, in mats on flat rocks in the litoral zone.

*5. S. crustaceum Agardh ex Bornet & Flahault, 1887, p. 106. On sand near Mangrove Creek, Hamilton, Jan., Farlow.

Tolypothrix Kützing.

*T. tenuis Kützing ex Bornet & Flahault, 1887, p. 122; Kützing, 1850–52, p. 9, Pl. XXXI, fig. II. Among *Oedogonium*, in ditch in Devonshire Marsh, April, Collins.

Hassallia Berkeley.

*H. byssoidea Hassall ex Bornet & Flahault, 1887, p. 116. On bark of *Juniperus bermudiana*, rather common.

Family STIGONEMACEAE Hassall.

Mastigocoleus Lagerheim.

M. testarum Lagerheim ex Bornet & Flahault, 1887, p. 54; 1889, p. CLXII, Pl. X, fig. 4. In dead shells of mollusks, with *Gomontia* etc.

Hapalosiphon Nägeli.

*H. intricatus W. & G. S. West, 1895, p. 271, Pl. XV, figs. 16–28; P. B.-A., No. 1855. In ditch in Devonshire Marsh, April, Dec., Collins.

Stigonema Agardh.

*S. informe Kützing ex Bornet & Flahault, 1887, p. 75; Kützing, 1850–1852, p. 15, Pl. XXXVIII, fig. 3. Feb., H. Kennedy in Farlow herbarium.

Fischerella Gomont.

*F. ambigua Gomont, 1895, p. 49, Pl. III. On stone wall, Jan., Farlow.

FAMILY RIVULARIACEAE.

CALOTHRIX Agardh.

1. Heterocysts basal only.	2.
1. Heterocysts basal and intercalary.	6.
2. Trichomes violet.	1. C. fusco-violacea.
2. Trichomes olivaceous or aerugineous.	3.
3. More or less endophytic.	3. C. parasitica.
3. Not endophytic.	4.
4. Filaments in stellate tufts on other algae.	6. C. confervicola.
4. Filaments not in stellate tufts; saxicolous.	5.
5. Trichomes olivaceous.	2. C. scopulorum.
5. Trichomes aerugineous.	4. C. aeruginea.
6. Filaments attached at the middle.	7. C. pilosa.
6. Filaments attached at one end.	7.
7. Filaments 9–10 μ diam.	4. C. aeruginea.
7. Filaments 12–40 μ diam.	5. C. crustacea.

1. C. FUSCO-VIOLACEA Crouan ex Bornet & Flahault, 1886, p. 352; P. B.-A., No. 2060. On *Enteromorpha*, *Ectocarpus* etc., rock pool, South Shore, Jan., Hervey.

2. C. SCOPULORUM Agardh ex Bornet & Flahault, 1886, p. 353; Bornet & Thuret, 1880, p. 159, Pl. XXXVIII; P. B.-A., No. 1856. On flat rocks between tides, Causeway, Shelly Bay, etc., common.

3. C. PARASITICA Thuret ex Bornet & Flahault, 1886, p. 357; Bornet & Thuret 1880, p. 157, Pl. XXXVII, figs. 7–10. In *Trichogloea Herveyi*, Cooper's Island, April, Collins; in gelatinous mass of various algae, in drip from Aquarium outlet, Aug., Collins. Occasionally found in various loose-tissued algae.

4. C. AERUGINEA Thuret ex Bornet & Flahault, 1886, p. 358; Bornet & Thuret, 1880, p. 157, Pl. XXXVII, figs. 1–6. On rocks, North Shore, mixed with *Schizothrix* etc., Nov., Hervey.

5. C. CRUSTACEA Thuret ex Bornet & Flahault, 1886, p. 359; Bornet & Thuret, 1876, p. 13, Pl. IV. Spanish Rock, April; on *Sargassum*, Gravelly Bay, Dec., Hervey.

6. C. CONFERVICOLA Agardh ex Bornet & Flahault, 1886, p. 349; Bornet & Thuret, 1876, p. 8, Pl. III. On *Cladophora crystallina*, Harrington Sound, Collins.

7. C. PILOSA Harvey ex Bornet & Flahault, 1886, p. 363; Harvey, 1858, p. 106, Pl. XLVIII. C. Common in shallow pools and on flat rocks between tides.

DICHOTHRIX Zanardini.

1. On rocks; filaments 15–20 μ in branches of last order. 1. D. Baueriana.
1. Epiphytic; filaments 20–30 μ in branches of last order. 2. D. fucicola.

*1. D. BAUERIANA Bornet & Flahault, 1886, p. 376. On rocks between tides, North Shore, Oct., Nov., Hervey; Hamilton Harbor, Nov., Collins. Known heretofore only as a fresh water species, but the Bermuda plant is distinctly marine, though agreeing in characters with European and American specimens from fresh water stations.

2. D. FUCICOLA Bornet & Flahault, 1886, p. 379; *Schizosiphon fucicola* Kützing, 1850–52, p. 18, Pl. LV, fig. II. On various algae forming a mat at the bottom of a pool, Gibbet Island, Hervey.

POLYTHRIX Zanardini.

P. CORYMBOSA Grunow ex Bornet & Flahault, 1886, p. 380; P. B.-A., No. 1903; *Microcoleus corymbosus* Harvey, 1858, p. 109, Pl. XLVIII. B. Common on rocks between tides in quiet water all around the islands.

RIVULARIA Roth.

R. POLYOTIS Bornet & Flahault, 1886a, p. 360; P. B.-A., No. 1904; *R. hospita* Bornet & Thuret, 1880, p. 168, Pl. XLI. Rocks near high water, South Shore, Feb., April, Collins; grotto, Tucker's Town, Dec., Hervey.

BRACHYTRICHIA Zanardini.

B. MACULANS Gomont, 1901, p. 127, Pl. V, figs. 5–7; P. B.-A., No. 2159. Forming a thin film on roots etc. of mangroves between tides, in company with *Dichothrix* and *Calothrix* species, Fairyland, Dec., Collins.

Originally described from material collected in Siam, this species now makes its second appearance half way round the globe.

FAMILY CRYPTOGLENACEAE.

CRYPTOGLENA Ehrenberg.

C. AMERICANA B. M. Davis, 1894, p. 101, Pl. XI; P. B.-A., No. 1851. Among *Cladophora expansa* and other algae, in a brackish pool between Harrington Sound and the North Shore, April, Collins.

CLASS **CHLOROPHYCEAE.**

FAMILY DESMIDIACEAE.

CLOSTERIUM Nitzsch.

1. Apices subacute; median diam. 17–37 μ. 1. C. Leibleinii.
1. Apices obtuse; median diam. 33–50 μ. 2. C. moniliferum.

*1. C. LEIBLEINII Kützing ex Ralfs, 1848, p. 167, Pl. XXVIII, fig. 4; Wolle, 1884, p. 46, Pl. VII, figs. 13, 14, 20; G. S. West, 1904, p. 141, Pl. XVI, figs. 9–14; P. B.-A., No. 2061. In small quantity in an artificial reservoir for fresh water, near Spanish Rock, Dec., Hervey.

*2. C. MONILIFERUM Ehrenberg ex Ralfs, 1848, p. 166, Pl. XXVIII, fig. 3; Wolle, 1884, p. 45, Pl. VII, fig. 15; G. S. West, 1904, p. 142, Pl. XVI, figs. 15–16; P. B.-A., No. 1961. Very abundant in an artificial reservoir for fresh water, near Spanish Rock, Dec., Hervey.

COSMARIUM Corda.

1. Uniformly granulate; semi-cell ovate-pyramidal, 51–68 μ wide. 4. C. botrytis.
1. Smooth. 2.
    2. Semi-cell semicircular to semielliptic; 34–36 μ broad. 1. C. Cucumis.
    2. Semi-cell truncate-pyramidal, 19–30 μ broad. 2. C. granatum.
    2. Semi-cell trapezoidal to truncate-pyramidal; about 33 μ broad. 3. C. pseudonitidulum.

*1. C. CUCUMIS Corda ex Ralfs, 1848, p. 93, Pl. XV, fig. 2; G. S. West, 1905, p. 152, Pl. LIX, figs. 18–20; P. B.-A., No. 1858. Among *Sphagnum* in a ditch, Devonshire Marsh, April, Collins. Distributed as *C. subcucumis* Schmidle, but agreeing better with *C. Cucumis.*

*2. C. GRANATUM Brébisson in Ralfs, 1848, p. 96, Pl. XXXII, fig. 6; Wolle, 1884, p. 60, Pl. L, fig. 13; G. S. West, 1905, p. 186, Pl. LXIII, figs. 1–3. Rather scanty, among *Oedogonium Itzigsohnii,* ditch in Devonshire Marsh, April, Collins.

*3. C. PSEUDONITIDULUM Nordstedt, 1873, p. 16, Pl. I, fig. 4; Wolle, 1884, p. 62, Pl. XVIII, fig. 19; G. S. West, 1905, p. 195, Pl. LXIII, fig. 26; P. B.-A., No. 2063. Among various algae in a ditch in South Shore marshes, Sept., Collins.

*4. C. BOTRYTIS Meneghini ex Ralfs, 1848, p. 99, Pl. XVI, fig. 1; Wolle, 1884, p. 74, Pl. XIII, fig. 5; G. S. West, 1911, p. 1, Pl. XCVI, figs. 1, 2, 5–15; P. B.-A., No. 2062. In artificial reservoir for fresh water near Spanish Rock, Dec., Hervey.

MESOTAENIUM Nägeli.

*M. ENDLICHERIANUM Nägeli, 1849, p. 109, Pl. VI. B; G. S. West, 1904, p. 56, Pl. IV, figs. 20–21; P. B.-A., No. 1857. Among other algae in a ditch, fresh water or nearly so, Devonshire Marsh, April, Collins.

FAMILY ZYGNEMACEAE.

SPIROGYRA Link.

S. SUBMARINA (Collins) Transeau, 1915, p. 25; *S. decimina* var. *submarina* Collins, 1909, p. 110; 1912, p. 72. Ditch in South Shore marshes, Sept., Collins. This was first described as a variety of *S. decimina,* which it considerably resembles, and it was known from three widely separated stations in New England. The Bermuda material emphasizes the differences from *S. decimina;* the long cells, up to 8 diam., and the considerably swollen fertile cells; the material from the Elizabeth Islands, Collins, 1912, p. 72, has cells as small as 21 μ diam.

FAMILY VOLVOCACEAE.

A *Chlamydomonas* was found in abundance in the water of an old tank, near Trott's Pond, Aug., Collins, but we have not been able to determine the species.

FAMILY TETRASPORACEAE.

TETRASPORA Link.

*T. LUBRICA (Roth) Agardh, 1824, p. 188; Collins, 1909, p. 139, fig. 26; *Ulva lubrica* Roth, 1806, p. 168. On dead leaves in ditch in Devonshire Marsh, Dec., Collins.

FAMILY PROTOCOCCACEAE.

PROTOCOCCUS Agardh.

*P. VIRIDIS Agardh, 1824, p. 13; *Pleurococcus vulgaris* Nägeli, 1849, p. 65, Pl. IV. E, fig. 2; Collins, 1909, p. 304, fig. 106. On shady side of trees, walls etc., all over the island; it occurs in similar stations in all temperate regions, and possibly also in tropical. Wille, 1913, p. 3, Pl. I, fig. 1, has pointed out the confusion that has long existed in regard to this species and *Pleurococcus vulgaris* Meneghini, and by examination of type specimens, cleared up the matter.

CHLOROCYSTIS Reinhard.

C. COHNII (Wright) Reinhard, 1885, p. 4, Pl. I; Moore, 1900, p. 100, Pl. X; Collins, 1909, p. 148, fig. 35; *Chlorochytrium Cohnii* Wright, 1877, p. 367, Pl. IV–V. In *Ulva Lactuca*, Hungry Bay, April, Collins. Spores, apparently the smaller kind, had been formed in some of the cells.

FAMILY SCENEDESMACEAE.

OOCYSTIS Nägeli.

*O. BORGEI Snow, 1903, p. 379, Pl. II, fig. VII; Collins, 1909, p. 160. Among *Oedogonium Itzigsohnii*, in ditch in Devonshire Marsh.

SCENEDESMUS Meyen.

*S. BIJUGA (Turp.) Wittrock, Nordstedt & Lagerheim, Alg. Exsicc., No. 1567; Collins, 1909, p. 168; *Achnanthes bijuga* Turpin, 1828, p. 310, Pl. XIII, fig. 4. Among *Rhizoclonium hieroglyphicum* in an artificial reservoir near Spanish Rock, Dec., Hervey.

FAMILY ULOTHRICHACEAE.

GEMINELLA Turpin.

G. SCALARIFORMIS forma **marina** G. S. West in litt.; P. B.-A., No. 2002. Forming a floating gelatinous mass in an upper tide pool, at the entrance to Hungry Bay, April, Collins. The typical form of this species is a fresh water plant from Barbados, described and figured as *Hormospora scalariformis* by G. S. West, 1904a, p. 282, Pl. CCCCLXIV, figs. 6–7. In the Bermuda plant the cells are sometimes longer in proportion to the diameter, and the wall of the filament shows no differentiated portion about the individual cell. It is probable that *Hormotrichum bermudianum* Harvey is the same plant, but the specimens of the latter cannot be found. Rein, 1873, p. 153, gives this name as Harvey, sp. n. Dr. Möbius has kindly looked for it in the collection at Frankfort, and was unable to find it. Professor Dixon of the University of Dublin tells us that he cannot find it in the Harvey herbarium. The *nomen nudum* cannot of course stand against West's name, but it would be of interest to recover the material.

STICHOCOCCUS Nägeli.

*S. SUBTILIS (Kütz.) Klercker, 1896, p. 103; Hazen, 1902, p. 162, Pl. XXI, figs. 10–13; Collins, 1909, p. 191; *Ulothrix subtilis* Kützing, 1845, p. 197. Among other algae, in a ditch in South Shore marshes, Aug., Collins. Straight filaments a few cells long, scattered among *Spirogyra, Rhizoclonium* etc.

MICROSPORA Thuret.

1. Cells thick-walled, 20 μ or more diam.	1. M. Wittrockii.
1. Cells thin-walled, 11–14 μ diam.	2. M. Willeana.

*1. M. WITTROCKII (Wille) Lagerheim, 1887, p. 417; Hazen, 1902, p. 172, Pl. XXIII, figs. 5–7; Collins, 1909, p. 193; P. B.-A., No. 2066; *Conferva Wittrockii* Wille, 1887, p. 461, Pl. XVII, figs. 35–41. Fresh water pool near Shark's Hole, Feb., Hervey.

*2. M. WILLEANA Lagerheim in De Toni, 1889, p. 228; Hazen, 1902, p. 175, Pl. XXIV, figs. 5–7; Collins, 1909, p. 194. Among *Oedogonium* etc. in ditch in Devonshire Marsh, April, Collins.

FAMILY ULVACEAE.

ENTEROMORPHA Link.

1. Cells not in longitudinal series except in the very youngest parts.	2.
1. Cells mostly in longitudinal series.	3.
2. Cells 10–20 μ diam.	6. E. intestinalis.

2. Cells 5–7 μ diam. 2. E. minima.
3. Fronds simple or with a few proliferations. 4.
3. Fronds more or less branched. 5.
4. Fronds inflated and flexuous. 5. E. flexuosa.
4. Fronds compressed-filiform. 3. E. marginata.
5. Branches largely monosiphonous. 1. E. plumosa.
5. Branches not monosiphonous, except occasional proliferations. 4. E. prolifera.

1. E. PLUMOSA Kützing, 1843, p. 300, Pl. XX, fig. 1; Collins, 1909, p. 198; Börgesen, 1913, p. 7; P. B.-A., No. 2065; *E. Hopkirkii* Vickers, 1908, Pl. V. Rein, as *E. percursa;* North Shore, Jan., Gibbet Island, Feb., March, Devonshire Bay, Feb., Harris Bay, March, Hervey; Tucker's Town, Harrington Sound, Shelly Bay, April, Hungry Bay, May, Inlet, Aug., Collins. The most frequent species of the genus here and quite distinct from our other forms, by the rather large, longitudinally seriate cells, and the many branches of a few series or a single series of cells. Sometimes long, subsimple branches occur, of two series of cells, much resembling *E. percursa* (Ag.) J. Ag, with which a plant of this kind was identified by Rein. It is the *E. plumosa* of Börgesen, the *E. Hopkirkii* of Vickers, as shown by authentic specimens; whether the plants passing under these names in the North Atlantic are identical with this and with each other may be questioned. If there should prove to be two species, an examination of original specimens would be needed to decide what names to use.

2. E. MINIMA Nägeli in Kützing, 1849, p. 482; 1856, p. 16, Pl. XLIII, fig. 3; Collins, 1909, p. 201; P. B.-A., No. 2005. Grasmere, March, Hervey; on old fish car, Hungry Bay, April, in drip from outlet of aquarium, Agar's Island, Aug., Collins.

3. E. MARGINATA J. G. Agardh, 1842, p. 16; Kützing, 1856, p. 15, Pl. XLI, fig. 1; Collins, 1909, p. 202. On old *Sargassum,* below Flatts Bridge, May, Collins.

4. E. PROLIFERA (Fl. Dan.) J. G. Agardh, 1882, p. 129, Pl. IV, figs. 103–104; Collins, 1909, p. 202; *Ulva prolifera* Flora Danica, Vol. V, p. 5, Pl. DCCLXIII, 1782. Rein, as *E. compressa.* Rein's specimen is the only one of the species that we have seen from Bermuda, but it may be not uncommon. Little branched forms might easily be mistaken for *E. minima* or *E. flexuosa,* until examined microscopically.

5. E. FLEXUOSA (Wulf.) J. G. Agardh, 1882, p. 126; Collins, 1909, p. 203; P. B.-A., No. 2004; *Conferva flexuosa* Wulfen, 1803, p. 15. Miss Peniston; Harrington Sound, Feb., Dec., Devonshire Bay, Feb.,

Inlet, March, Hervey; Harrington Sound, April, Collins. In some specimens cells may be found as large as 20 μ square, but in other parts of the same individual they are of normal dimensions, little over 12 μ.

Forma **submarina** f. nov.; P. B.-A., No. 2161. Natans: frondibus inflatis, contortis.

Floating; fronds inflated, contorted. In extensive floating mats in brackish water, near old race course, Dec., Collins.

6. E. INTESTINALIS (L.) Grev. forma TENUIS Collins, 1903, p. 23; 1909, p. 205; P. B.-A., No. 2003. In brackish water, South Shore marshes, Aug., Collins. The thickness of the frond, 20–30 μ, is greater than that of the plant on which this form was founded. The latter grew in fresh water, remote from the sea; the present form, growing in brackish water, may be considered as intermediate between the form from fresh water and the typical species growing in the sea. A specimen in the Kemp herb., marked *Ulva linza,* seems to be typical *E. intestinalis,* but it is not in good enough condition for certainty.

Monostroma Thuret.

1. Frond 25 μ thick or less, cells more or less in twos and fours. 1. M. latissimum.
1. Frond 30 μ thick or more; cells not in twos or fours. 2. M. orbiculatum.

1. M. LATISSIMUM (Kütz.) Wittrock, 1866, p. 33, Pl. I, fig. 4; Collins, 1909, p. 211; P. B.-A., No. 1859; *Ulva latissima* Kützing, 1856, p. 7, Pl. XIV. On mangroves just below Flatts Bridge; on *Salicornia,* Hungry Bay, April, Collins. This plant made its first appearance at Flatts Bridge about the middle of April, 1912, and grew rapidly. None was to be seen at the same station from July to September, 1913, nor elsewhere during those months.

2. M. ORBICULATUM Thuret, 1854, p. 388; Wittrock, 1866, p. 37, Pl. II, fig. 6; Collins, 1909, p. 212; Alg. Am.-Bor. Exsicc., No. 173. The material collected and distributed by Farlow is all that is recorded for Bermuda.

Ulva Linnaeus.

1. Frond divided into linear lobes. 2. U. fasciata.
1. Frond rounded or of irregular outline. 1. U. Lactuca.

1. U. LACTUCA L. var. LATISSIMA (L.) De Candolle, 1805, p. 9; Collins, 1909, p. 215. Rein; Moseley; April, June, Kemp, as *U.*

latissima; in high pool near Tucker's Town, April, Collins; in quiet waters elsewhere, but less common than var. *rigida.*

Var. RIGIDA (Ag.) Le Jolis, 1863, p. 38; Collins, 1909, p. 215; P. B.-A., No. 2064; *U. rigida* Agardh, 1822, p. 410. Rein; Kemp, as *U. Lactuca;* Tobacco Bay, Grasmere, March, Harrington Sound, July, Hervey; Inlet, Aug., Collins. Rather common both in sheltered and exposed places; sometimes quite near to *U. fasciata.*

2. U. FASCIATA Delile, 1813, p. 153, Pl. LVIII, fig. 5; Collins, 1909, p. 216. Miss Wilkinson; Harrington Sound, March, Hervey. Apparently not common; not easy to distinguish from forms of *U. Lactuca var. rigida,* but generally of darker color, especially near the margin of the linear, dentate or crenate lobes; the frond is thicker than in most forms of *U. Lactuca,* and the cells more elongate vertically.

PROTODERMA Kützing.

P. MARINUM Reinke, 1889, p. 81; Collins, 1909, p. 217. On pebbles, North Shore near Inlet, Aug., Collins. Probably common everywhere but inconspicuous.

FAMILY CYLINDROCAPSACEAE.

CYLINDROCAPSA Reinsch.

*C. INVOLUTA Reinsch, 1867, p. 66, Pl. VI, fig. 1; P. B.-A., No. 2067; *C. geminella* Wolle, 1887, p. 104, Pl. XCI, figs. 1–17; Collins, 1909, p. 222; *C. geminella* var. *minor* Hansgirg, 1886, p. 224, fig. 122; *Hormospora geminella,* Wolle, 1877, p. 140. In artificial reservoir near Spanish Rock, among *Rhizoclonium hieroglyphicum* etc., Feb., Hervey. In explanation of the synonymy just given, we must go into a little detail. The genus *Cylindrocapsa* and the species *C. involuta* were founded by Reinsch on vegetative characters only; the fructification was discovered by Cienkowski, described and well figured by him, 1876, p. 560, Pl. IX, figs. 50–65. Wolle, 1877, p. 140, described *Hormospora geminella,* vegetative characters only; in 1887, p. 104, *Cylindrocapsa geminella* with description of fructification. Pl. XCI, figs. 1–17 is supposed to represent the latter, but is not very instructive. No reference is made to *Hormospora geminella.* Hansgirg, 1886,[7] p. 223,

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[7] The date on the first title of the Prodromus is 1886; a second title, introducing a "Schlusswort" with separate paging, is dated 1888; under *C. geminella* there is a reference to the author's "Phyc. u. algol. Studien, 1887."

records for Bohemia "*C. geminella* Wolle (*Hormospora geminella* Wolle Bull. of the Tor. Bot. Club 1877)" and describes var. *minor.* The diameter of cells given for the typical *C. geminella,* 20–24 μ, does not agree with Wolle's figures, 16–21 μ for *Hormospora,* 14–16 μ for *Cylindrocapsa,* but are nearer *C. involuta* Reinsch, 23–30 μ. Hansgirg's var. *minor* is said to be 12–15 μ, diam., exceptionally 18–25 μ, in very young filaments 9–12 μ, which would certainly include Wolle's *C. geminella.* On comparing all the descriptions and figures, we can find no real distinction between *C. involuta, C. geminella* and *C. geminella* var. *minor;* and in the Bermuda material we can match practically every figure. We have therefore used the oldest name.

Family OEDOGONIACEAE.

Oedogonium Link.

1. Oogonium with a whorl of conical projections. 3. O. Itzigsohnii.
1. Oogonium without whorl of projections. 2.
  2. Filaments 14–20 μ diam. 1. O. Pringsheimii.
  2. Filaments seldom over 12 μ diam., usually in stellate clusters. 2. O. consociatum.

*1. O. Pringsheimii Cramer ex Hirn, 1900, p. 170, Pl. XXVII, fig. 155; Collins, 1909, p. 246; P. B.-A., No. 1861. In ditch in Devonshire Marsh, April, Collins.

*2. **O. consociatum** sp. nov. Plate I, figs. 1–4; P. B.-A., No. 2068. Diocum (?), macrandrium; oogonia solitaria, globosa vel depresso-globosa, operculata, rima mediana vel subsuperiore, angusta sed distincta; oospora globosa vel depresso-globosa, oogonium implente, membrana laevi; cellula basali depresso-globosa; cellulis vegetativis plus minusve distincte clavatis.

Dioecious (?), macrandrous; oogonia single, globose to depressed-globose, operculate, division median to superior, narrow but distinct; oospore globose to depressed globose, filling the oogonium, membrane smooth; basal cell depressed-globose; vegetative cells more or less distinctly clavate.

veg. cell, female,	6–12 (20) μ	diam.,	1–4	diam. long.
oog.	28 μ	"	26–28 μ	"
oosp.	26 μ	"	24–26 μ	"

In an artificial fresh water reservoir near Spanish Rock, Jan., Hervey, Aug., Collins. Type in herb. Collins, No. 7812.

The basal cell is depressed-globose, 20–24 μ diam., 12–16 μ high; the first cell above is 6–8 μ diam., 2–3 diam. long; the filament may continue of the same diameter, or may increase up to 12 μ, the cells 1–2 diam. long; occasionally the diam. reaches 20 μ, the cells about one diam. long and moniliform; at any point a larger filament may suddenly change to the smaller diameter, a cell of 8–10 μ following a cell of 12–20 μ. Oogonia were not uncommon, but were very generally abortive; in the few instances where they seemed normal they were regularly globose, and contained a globose oospore, quite filling the oogonium, of orange yellow color. The division of the oogonium was median or slightly higher; no antheridia were seen.

The study being made from formalin material, the development of the zoospores could not be followed, but they must have been produced in immense numbers. Cells of *Pithophora kewensis* were seen, completely covered with zoospores which had affixed themselves, but still retained the spherical form, and were 16–24 μ diam.; the appearance was much like that of a filament of *Lyngbya* covered with *Xenococcus*, as shown in Bornet & Thuret, 1880, Pl. XXVI, fig. 1. The zoospores seemed to secrete some adhesive substance from the cell wall, forming a sort of collar underneath the cell, extending beyond the diameter of the cell, so as to be visible from above as well as from the side. Something similar is seen in *Chantransia collopoda* Rosenvinge, 1898, fig. 10, A. As the densely packed zoospores germinate, the host soon becomes indistinguishable, the sporelings forming a bristly mass, to the filaments of which more zoospores attach themselves, adhering to the young *Oedogonium* filaments in the same way as to the *Pithophora*. It seems probable, however, that often the zoospores adhere to each other in a larger or smaller rounded mass; when they germinate the radiating filaments form an echinate body, which is different from anything we find recorded for the genus, except the figures of *O. pachyandrium* in Wolle, 1887, Pl. LXXIII, figs. 38 and 39.

These figures though rude and in no way showing the evolution of the cluster, give a fair idea of the appearance. These masses often contain hundreds, probably thousands of spores, and before germination has much progressed, look like bits of fish roe. In the material of No. 7812 the *Pithophora* appeared to be fairly smothered by the *Oedogonium*, many of the cells dead; the greater part of the spores were attached to *Oedogonium* filaments or to each other; in No. 7368 material the *Oedogonium* was less abundant, and except a few loose clusters was all on the *Pithophora,* which was still uninjured; *Rhizoclonium hieroglyphicum* was much more common in this material than *Pithophora,* but was quite free from the *Oedogonium.* The nearest relative would seem to be *O. inversum* Wittr., which has capitate cells of approximately the same size, and a broadened basal cell, but has cells uniformly 12–14 μ diam., and up to 8 diam. long; rather larger oospores, with quite low division; the basal cell is attached by the flat lower surface, while in *O. consociatum* the lower surface is convex, resting in the ring by which it is affixed to the host.

*3. O. ITZIGSOHNII De Bary ex Hirn, 1900, p. 177, Pl. XXVIII, fig. 167; Collins, 1912, p. 86; P. B.-A., No. 1860. In ditch, Devonshire Marsh, April, Collins.

Sterile filaments of at least two other species have been found in collections from a roadside pool near Old Ferry Road, Aug., and from a ditch in South Shore marshes, Sept., Collins.

FAMILY CHAETOPHORACEAE.

DIPLOCHAETE Collins.

D. SOLITARIA Collins, 1901, p. 242; 1909, p. 278, fig. 99. Occasional individuals on *Laurencia* and other algae, never in any abundance.

BLASTOPHYSA Reinke.

B. RHIZOPUS Reinke, 1889a, p. 27, Pl. XXIII; Börgesen, 1911, p. 151, fig. 13; 1913, p. 8, fig. 2; Collins, 1912, p. 99, fig. 12; P. B.-A., No. 1905. South Shore, Jan., Hervey; marsh near racecourse, Aug., Collins. At the South Shore in the basal layer of a growth of *Sphacelaria tribuloides;* at the marsh on *Ruppia maritima,* among other small algae; in *Ulva Lactuca,* Harrington Sound, Aug., Collins.

PHAEOPHILA Hauck.

P. FLORIDEARUM Hauck, 1876, p. 57; 1885, p. 464, fig. 200. Harris Bay, Jan., Hervey. This minute plant occurred among various other algae from a pool, the whole forming a thin, crisp, light green incrustation of about the consistency of some thin, encrusting sponge. It is probably not uncommon, but is easily overlooked, as it can be found only by microscopic examination. It has been found in small quantity in *Halymenia bermudensis,* Grasmere, March, Hervey.

ENDODERMA Lagerheim.

1. Cells mostly irregular.	1. E. viride.
1. Cells mostly cylindrical.	2. E. filiforme.

1. E. VIRIDE (Reinke) Lagerheim, 1883, p. 74; Collins, 1909, p. 279; P. B.-A., No. 2006; *Entocladia viridis* Reinke, 1879, p. 476, Pl. VI, In the cell wall of various algae, common.

2. **E. filiforme** sp. nov. Filamentis lateraliter vel dichotome ramosis, cellulis vegetativis cylindricis, prope apices circa 2 μ diam., longitudine diametrum pluries superante; inferne ad 6 μ diam., longitudine diametrum duplo superante, forma plus minusve irregulari; quavis cellula matura in sporangium mutata, circumscriptione circulari supra visa, 6–12 μ diam., depresso-hemisphaerica lateraliter visa, membrana crassa; prolongatione papilliformi per membranam plantae hopsitis protrusa, mox aperta ad exitum sporarum (?); sporis (?) 2 μ diam., in cellula paucis; setis, cellulae continuis, haud raro membranam hospitis penetrantibus, basi circa 4 μ diam., mox ad 2 μ attenuatis, neque bulbosis nec constrictis; chromatophora parietali, pyrenoideo unico, magno, munita.

Filaments branched laterally or dichotomously; vegetative cells cylindrical, near apex about 2 μ diam. and several diam. long, below up to 6 μ diam. and 2 diam long, more or less irregular; any cell of the older portion changing to a sporangium, circular in outline seen from above, 6–12 μ diam., depressed hemispherical in side view, with thick wall; a small papilla-like extension passing through the wall of the host, then opening to permit the exit of the spores (?); spores about 2 μ diam., few in a cell; bristles continuous with the cell also occasionally passing through the wall of the host, the base about 4 μ diam., quickly tapering to 2 μ, no constriction or bulb. In wall of *Lyngbya confervoides,* Bailey's Bay, Jan. 18, 1913, Hervey. Type in Collins herbarium, No. 7419a.

The older part is not unlike *E. viridis,* but the long, very slender, often quite straight filiform branches distinguish it from that as well as from other species; these branches seem usually to run lengthwise of the host, dividing mostly dichotomously; the older cells increase rapidly in width, and send off many branches at right angles, often in secund series, passing around the host; in older plants the branching may be quite dense, with no regularity discernible. The wall is very thin in the younger cells, but becomes quite thick in the older; the chromatophore is dense, and nearly or quite covers the wall. Bristles appear to be rare, and those we saw were short, evidently broken off. In the oldest parts of the plant, most of the cells had become sporangia, many of them had emptied, and only one was seen containing spores; these appeared spherical, but no details could be made out from the formalin material. The host has thick, distinctly laminate walls, and the Endoderma seems to push apart the laminae without difficulty; in one case two plants were seen, one outside the other, separated by one of the laminae of the host. In another case a plant was seen quite on the outside of the host wall; in this the cells were quite small and spherical; it seems probable that the lamina of the host under which they grew had peeled off, and the cells took the unusual form on release of the pressure.

Pringsheimia Reinke.

P. scutata Reinke, 1889a, p. 33, Pl. XXV; Collins, 1909, p. 288, fig. 95. On *Wurdemannia*, Gibbet Island, Aug., Collins; on *Ulva*, Harrington Sound, Aug., Collins.

Microthamnion Nägeli.

*M. Kuetzingianum Nägeli in Kützing, 1849, p. 352; Hazen, 1902, p. 191, Pl. XXVI, fig. 1; Pl. XXVII, figs. 2–4; Collins, 1909, p. 294. Among *Tetraspora lubrica*, on dead leaves in ditch in Devonshire Marsh, Dec., Collins.

Urococcus Kützing.

*U. insignis (Hass.) Kützing, 1849, p. 207; Wolle, 1887, p. 201, Pl. CXXIII, figs. 11–12; Collins, 1909, p. 306; P. B.-A., No. 1862; *Haematococcus insignis* Hassall, 1845, p. 324, Pl. LXXX, fig. 6. Among *Sphagnum* in Devonshire Marsh, April, Collins.

Gloiococcus A. Braun.

*G. mucosus A. Braun, 1851, p. 170; Collins, 1909, p. 310, fig. 122. Among *Oedogonium* etc., in ditch in Devonshire Marsh, April, Collins.

FAMILY TRENTEPOHLIACEAE.

TRENTEPOHLIA Martius.

*T. AUREA (L.) Martius, 1817, p. 351; Collins, 1909, p. 316; *Byssus aureus* Linnaeus, 1753, p. 1168. Common on shaded cliffs all over the islands, forming little orange-colored tufts of soft filaments, sometimes confluent and covering considerable spaces.

FAMILY CLADOPHORACEAE.

CHAETOMORPHA Kützing.

1. Filaments under 100 μ diam.	2.
1. Filaments over 100 μ diam.	3.
2. Filaments attached, not over 25 μ diam.	1. C. minima.
2. Filaments not attached, 40–70 μ diam.	2. C. gracilis.
3. Filaments 500 μ diam. or more.	5. C. crassa.
3. Filaments 400 μ diam. or less.	4.
4. Light green; filaments 200–250 μ diam.	4. C. Linum.
4. Dark green; filaments 125–175 μ diam.	3. C. brachygona.

1. **C. mimima** sp. nov.; Plate I, figs. 5–7; P. B.-A., No. 2007. Filamentis disco affixis, cylindricis vel plus minusve clavatis, 10–20 μ diam., ad nodos interdum constrictis; cellulis 2–4 diam. longis, membrana crassa distincte laminata; zoosporis (?) in quavis cellula formatis, per foramine laterale liberatis.

Filaments attached by a disk, cylindrical or more or less clavate, 10–20 μ diam., nodes sometimes constricted; cells 2–4 diam. long, wall distinctly laminate; zoospores (?) formed in any cell, escaping by a lateral opening in the wall. On fronds of *Codium, Cladophora* etc.

The smallest species yet known in this genus; *C. californica* Collins, P. B.-A., No. 664 was the smallest heretofore known in the attached state, and its filaments average about twice the diameter of the present species; as regards length, the contrast is even more striking, as in *C. californica* the fronds reach a length of a decimeter, while in *C. minima* 5 mm. is the longest observed. It was first found growing on the rounded ends of the utricles of *Codium tomentosum*, sometimes singly, sometimes many individuals close together. Being quite imperceptible to the eye, it was noticed only in the examination of the *Codium* material preserved in formalin, so that nothing can be said as to the characters of the supposed zoospores; everything was however similar to the formation and emission of zoospores in the larger and better known species of *Chaetomorpha*. Emptied cells were common, sometimes every cell of a filament being fertile, even the basal cell; in one instance a filament consisted of a single cell, which had emptied itself through the small round lateral opening. In the form of the cells, thick laminate wall, dense chromatophore with many pyrenoids, the plant is a microscopic copy of forms like *C. Linum*. Rather curiously, it is the only attached form we find in the islands. The type is in the Collins herbarium.

2. C. GRACILIS Kützing, 1845, p. 203; 1853, p. 17, Pl. LII, fig. 1 P. B.-A., No. 2162. Hungry Bay, in dense masses, April, Collins.

3. C. BRACHYGONA Harvey, 1858, p. 87, Pl. XLVI. A; Collins, 1909, p. 325. Fish pond, Walsingham, Nov., Hervey, lying loose on the bottom of the pond.

4. C. LINUM (Fl. Dan.) Kützing, 1845, p. 204; *C. aerea* forma *Linum* Collins, 1909, p. 325; P. B.-A., No. 1863. *Conferva Linum* Flora Danica, Vol. V, p. 4, Pl. DCCLXXI, 1782; Harvey, 1846–51, Pl. CL. A; Moseley; Rein, as *C. geniculata;* Hungry Bay, Pool by Moore's calabash tree, April, Collins; Walsingham, Causeway, Nov., Tucker's Town, Dec., Hervey. Common and variable.

5. C. CRASSA (Ag.) Kützing, 1845, p. 204; 1853, p. 19, Pl. LIX, fig. 11; P. B.-A., No. 1864; *Conferva crassa* Agardh, 1824, p. 99. Kemp, as *Hormotrichum;* Pool near Walsingham, April, Lagoon near Fairyland, Aug., Collins. Not always easily distinguishable from *C. Linum;* study of the various forms in their natural condition if continued over a considerable time, might lead to considerable rearrangement.

RHIZOCLONIUM Kützing.

1. Cells rarely under 30 μ diam., wall thick, often lamellate. 2.
1. Cells rarely over 30 μ diam., usually 10–25 μ. 3.
    2. Filaments 50–100 μ diam., usually with frequent short branches. 4. R. Hookeri.
    2. Filaments 33–44 μ diam. branching from basal cell only. 5. R. crassipellitum.
3. In fresh or slightly brackish water. 2. R. hieroglyphicum.
3. In salt water. 4.
    4. Cells 20–25 μ diam. 3. R. riparium.
    4. Cells 10–15 μ diam. 1. R. Kerneri.

1. R. KERNERI Stockmayer, 1890, p. 582; Collins, 1909, p. 329. Forming a coating on mangroves, Hungry Bay, April, Collins.

*2. R. HIEROGLYPHICUM (Ag.) Kützing, 1845, p. 206; Collins, 1909, p. 329; P. B.-A., No. 2009; *Conferva hieroglyphica* Agardh, 1827, p. 636; Pool in rock by Old Ferry landing, Aug.; ditch in South Shore marshes, Sept., Collins; artificial reservoir near Spanish Rock, Feb., Hervey. Mostly the typical form, but with some var. *macromeres* Wittr.

3. R. RIPARIUM (Roth) Harvey, 1846–51, Pl. CCXXXVIII; Collins, 1909, p. 327; *Conferva riparia* Roth, 1806, p. 216; Hungry Bay, April, Collins; Causeway, Nov., Hervey. On mangroves and other objects between tide marks; apparently not very common; mostly the form known as var. *implexum* (Dillw.) Rosenvinge.

4. R. HOOKERI Kützing, 1849, p. 383; 1853, p. 21, Pl. LXVII, fig. III; Collins, 1909, p. 330. Shore of Harrington Sound, April; Hungry Bay, May, Collins; Walsingham, Jan., Hervey. A rather coarse species, varying in diameter of filaments from 50 to 100 μ; the same filament is not infrequently double the diameter in one part that it is in another. The branches are mostly short, but have dense chromatophores the same as in the cells of the filament. Beside the localities given, it occurs on the walls of caves along high water mark, and on shaded sides of quarries, and even in reservoirs of quite fresh water.

5. R. CRASSIPELLITUM W. & G. S. West, 1897, p. 35; Collins, 1909, p. 330. In small pools, Ely's harbor, April, Hervey.

CLADOPHORA Kützing.

1. Fresh water.	19. C. fracta.
1. Marine.	2.
2. With distinction of prostrate and erect filaments.	16. C. Howei.
2. No distinct prostrate filaments.	3.
3. Forming a low matted expansion.	4.
3. Erect.	5.
4. Filaments 100–150 μ diam. throughout.	17. C. repens.
4. Filaments 70–100 μ diam. below, 60–80 μ above.	18. C. frascatii.
5. Main filaments 150 μ diam. and upwards.	6.
5. Main filaments seldom reaching 150 μ.	10.
6. Lower cells 10 diam. long or more.	14. C. catenifera.
6. Lower cells less than 10 diam. long.	7.
7. Diam. of filaments about the same throughout.	15. C. fuliginosa.
7. Terminal divisions markedly smaller than main axes.	8.

8. Ramuli clustered. 10. C. fascicularis.
8. Ramuli not clustered. 9.
9. Ultimate ramuli very short, often of a single cell; cells in ramuli ovoid, 1–2 diam. long. 8. C. brachyclona.
9. Ultimate ramuli not extremely short, cylindrical or nearly so. 13. C. utriculosa.
10. Cells generally with a sharp constriction near base. 3. C. constricta.
10. Cells without regular constrictions. 11.
11. Fronds floating except at earliest stages. 12.
11. Fronds always attached during active growth. 13.
12. Main filaments 30–60 μ diam. 4. C. crispula.
12. Main filaments, 100–150 μ diam. 7. C. expansa.
13. Main filaments distinctly angled or flexuous. 14.
13. Main filaments straight or nearly so. 15.
14. Pale yellow-green; cells 6–8 diam. long. 2. C. luteola.
14. Light to bright green; cells 2–6 diam. long. 6. C. flexuosa.
15. Main filaments 60 μ diam. or less. 1. C. delicatula.
15. Main filaments 80 μ diam. or more. 16.
16. Some branches decumbent, attaching by rhizoids. 5. C. corallicola.
16. No decumbent branches. 17.
17. Color pale, glossy, substance soft. 9. C. crystallina.
17. Color darker, substance crisp. 18.
18. Cells 3–5 diam. long; ramuli scattered. 11. C. piscinae.
18. Cells mostly 1–2 diam. long; ramuli closer and seriate. 12. C. rigidula.

1. C. DELICATULA Montagne, 1850, p. 302; Kützing, 1856, p. 1, Pl. I, fig. 2; Collins, 1909, p. 337; P. B.-A., No. 2070. Ely's Harbor, April, Hervey. Some of the plants were young and vigorous, reaching a length of 10 cm.; others were evidently old, the main branches with laminate walls up to 15 μ thick, and covered with minute epiphytes; new proliferous growth was very abundant, with delicate, thin walls, and generally like the younger plants.

2. C. LUTEOLA Harvey, 1858, p. 81; Collins, 1909, p. 338. Rein; Merriman in Farlow herb. We have not collected this species, and only these two records exist for Bermuda.

3. C. CONSTRICTA Collins, 1909a, p. 19, Pl. LXXVIII, figs. 4–5; 1909, p. 339. Hungry Bay, Feb., Hervey. Not over 3 cm. high, while the original material from Jamaica reached a height of 10 cm. The Bermuda plant occasionally sends out a very long, slender rhizoid from one of the lower cells; this has not been seen in the Jamaica material.

4. C. CRISPULA Vickers, 1905, p. 56; 1908, p. 19, Pl. XVI; Collins,

1909, p. 339; Börgesen, 1913, p. 24, fig. 15. P. B.-A., No. 2011. Harrington Sound, March, Hervey. To this species we have referred, with some doubt, a form found in floating masses, which agrees in size and length of cells, and in manner of branching, with *C. crispula*, but does not form contorted, rope-like strands. It seems to us that these may be a later development, and that our plant represents an earlier stage. Similar conditions are well known in species of *Rhizoclonium* and *Chaetomorpha*.

5. C. CORALLICOLA Börgesen, 1913, p. 21, figs. 11–12; P. B.-A., No. 2010. Tucker's Town, Dec., Hervey. Growing matted among old fronds of Bryopsis; the slender rhizoids characteristic of the species are well developed, and occasionally branch.

6. C. FLEXUOSA (Griff.) Harvey, 1846–51, Pl. CCCLIII; Collins, 1909, p. 339; *Conferva flexuosa* Griffiths in Wyatt, Alg. Danm., No. 227. Gibbet Island, June, Howe; North Shore, Tucker's Town, April, Inlet, Aug., Collins. A delicate plant but often reaching a length of 2 dm. Late in its season it becomes unattached and may be found in large floating masses, in Castle Harbor and similar places.

7. C. EXPANSA (Mert.) Kützing, 1853, p. 27, Pl. XCIX, fig. 1; Collins, 1909, p. 340; *Conferva expansa* Mertens in Jürgens, Algae Aquaticae, Dec. V. Brackish pool between North Shore and Harrington Sound, April, Collins. Forming loose floating masses, sometimes pure, sometimes in company with *Lyngbya* and *Enteromorpha*. In the latter case the algae form a felted stratum on the surface of the water so firm that the shore birds may be seen in large flocks, walking on it as if it were land, while they pick the small animals living among it. Whether this plant is the same as *C. heteronema* Kütz., as described by Börgesen, 1913, p. 25, may be a question. *C. flavescens* Harvey, 1846–51, Pl. CCXCVIII, Collins, 1909, p. 339, is certainly distinct, but we have not found it here; it seems to be a more northern form. Reinbold, 1893, p. 196, considers *Conferva expansa* of Jürgens Alg. Aquat. as distinct from *Cladophora fracta* forma *marina*, and refers for details to Farlow, 1881, p. 56; but the *C. fracta* forma *marina* of Farlow is a plant of much smaller filaments than the Hauck plant of the same name. We have found a plant in Harrington Sound, that could, without violence, pass for a slender form of *C. fracta* forma *marina* of Hauck, but it seems to us to fit equally well, if not better, in *C. expansa*, as we understand it.

8. C. BRACHYCLONA Montagne in Kützing, 1849, p. 394; 1853, p. 27, Pl. XCVI, fig. II; Collins, 1909, p. 344. A single specimen from Miss Peniston, without definite locality, is the only American

record for this Mediterranean plant. The specimen is well developed and characteristic.

9. C. CRYSTALLINA (Roth) Kützing, 1845, p. 213; 1854, p. 4, Pl. XIX, fig. II; Collins, 1909, p. 342; P. B.-A., No. 1865; *Conferva crystallina* Roth, 1797, p. 196. Rein, as *C. glaucescens;* Gravelly Bay, Feb., Dec., Hervey; Hungry Bay, April, North Shore, Harrington Sound, May, Collins. A handsome plant, soft and silky, growing on rocks on somewhat exposed shores, more commonly and luxuriantly in quiet water, where it sometimes becomes detached and continues growing in the floating state.

10. C. FASCICULARIS (Mert.) Kützing, 1843, p. 268; Vickers, 1905, p. 56; 1908, p. 18, Pl. XIII; Collins, 1909, p. 345; P. B.-A. No. 2163; *Conferva fascicularis* Mertens in Agardh, 1824, p. 114. Harrington Sound, Feb., Hervey. A quite variable species, common from Florida to South America, but found only once in Bermuda.

11. **C. piscinae** sp. nov. P. B.-A., No. 2165. Filamentis primariis 100 μ diam.; ramulis ultimis 50 μ; cellularum longitudine diametrum 3–5-plo superante; nodis haud constrictis; cellula terminali rotundata vel truncata, longitudine cellulas ceteras non superante; ramificatione inferne per dichotomias patentes, distantes, aequales, cellula dichotomias gerente plerumque sed non semper ceteris breviore; ramis superne ramulos distantes, patentes, ferentibus; colore laeteviridi; chromatophora laxe reticulata; substantia subcrispa, nec fragili.

Main filaments 100 μ diam.; ultimate ramuli 50 μ; length of cells 3–5 diam., nodes not constricted; terminal cell rounded or truncate, not longer than other cells; branching below by wide, equal, distant forkings, the cell bearing the forking usually but not always shorter than the others; above with distant patent ramuli; color light green; chromatophore a loose network; substance somewhat crisp but not fragile. In an old fishpool at Godet's Island, Nov. 30, 1915. Type in Collins herbarium, No. 8427.

The water in this pool is quite still, the tide having access only by small openings in the wall. The plant formed a loose mass, over one meter in diameter, the lower part caught on coral; the appearance was quite that of a loose *Spirogyra*. Though crisp to the touch, the fronds collapsed immediately on being taken from the water; the living plant is of a light green color, but this becomes dark in drying. There is some similarity in the characters above to those of the description of *C. Macallana* Harv., but that is a stouter and stiffer plant, with different habit. *C. patens* Kütz. has cells 4–8 diam. long, larger main filalents and smaller ramuli than *C. piscinae*. *C. crystallina*, the most nearly related Bermuda species, has larger main filaments, smaller and more closely set ramuli, longer cells, more fasciculate habit, softer substance, and does not become dark in drying.

12. **C. rigidula** sp. nov. Filamentis primariis circa 120 μ diam., secundi ordinis 100 μ, cellulis ultimis 80 μ; cellularum longitudine diametrum 1–2-plo superante; nodis haud constrictis; cellula terminali plerumque longiore, interdum ad 3 diam., rotundata vel subacuta; ramificatione prope basin per dichotomias patentes, primo approximatas, deinde distantes; ramis partis superioris frondis longis, rectis, ramulos gerentibus fere vel omnino sub angulo recto egredientes, distantes sparsosque inferne, in seriebus secundis prope apicem; colore viridi diluto obscuro; chromatophora subtiliter reticulata, pyrenoideos multos, minutos, nitidos monstrante; substantia firma crispaque.

Main filaments about 120 μ diam., secondary 100 μ, ultimate cells 80 μ; length of cells 1–2 diam., nodes not constricted; terminal cell usually longer, sometimes 3 diam., rounded or subacute; branching at base by broad forkings, at first frequent, later distant; branches in upper half of frond long, straight, with ramuli nearly or quite at right angles, distant and scattered below, near the tips in secund series; color rather dull light green; chromatophore a fine network with very many small bright pyrenoids; substance firm and crisp. In a stone tank above the bridge at Fairyland, Dec. 13, 1915. Type in Collins herbarium, No. 8513.

Though occurring in a station similar to that of *C. piscinae*, and in some points resembling the latter, it has seemed to us better to consider it a distinct species than to combine the two by too vague a description. *C. piscinae*, though crisp, promptly collapses when taken from the water, *C. rigidula* long keeps its shape and stiffness; the distinction is as marked as that between *Polysiphonia violacea* and *P. fastigiata*. In *C. piscinae* the cells are seldom under three or over five diam. long; in *C. rigidula* they are seldom over two diam., often only one diam. for a good part of the frond; the terminal cell is, however, often three diam. long. In both the ultimate ramuli are patent, often at a right angle; in *C. piscinae* they are scattered and usually distant, in C. rigidula closer and often in secund series. The differences can hardly be due to the station, as each grew in a stone tank, sea water going in and out with the tide, but with no active current, and no disturbance of the surface. On the other hand it has some resemblance to the plant from Harrington Sound which we distributed, P. B.-A., No. 2014, as *C. utriculosa*, but is still further removed from the typical Mediterranean form. In the latter the cells below are 6–8 diam. long, 2–4 diam. above, while in the present species only the terminal cell is usually over 2 diam. long. It seems to us safer to treat it as a new species than to put it in a species whose typical form, at least, is so distinct.

13. C. UTRICULOSA Kützing, 1843, p. 269; 1853, p. 26, Pl. XCIV, fig. I; Collins, 1909, p. 346; P. B.-A., No. 2014. Harrington Sound, Wadsworth, March; same station, Oct., Hervey. A common Mediterranean and West India species. Wadsworth's plants are rather more slender than the typical, but otherwise quite the same. The material collected by us in October formed loosely floating masses. evidently a later condition; all branching was wide; the dichotomies in the lower part about 120°, the ramuli, usually quite short, about 90°.

14. C. CATENIFERA Kützing, 1849, p. 390; 1853, p. 24, Pl. LXXXIII, fig. I; Collins, 1909, p. 347; P. B.-A., No. 2069. Kemp in herb., as *Cladophora* sp.?; Howe; Red Bay, St. David's Island, June, cave at Gravelly Bay, Feb., April, Dingle Bay, March, Hervey. The most striking of our species of the genus, with stout stem and main branches, very long cells, firm lustrous cell wall. Bermuda plants are 10–20 cm. high; at Jamaica it sometimes reaches a height of 50 cm. In February only very small plants were found.

15. C. FULIGINOSA Kützing, 1849, p. 415; Collins, 1909, p. 348; P. B.-A., No. 2012. Kemp, St. George's, unnamed specimen in herb.; Harris Bay, Jan., Apr., Gravelly Bay, Dec., Inlet, Dec., Hervey; Gravelly Bay, Aug., Collins. A coarse species, generally distributed and common; always infested with the fungus *Blodgettia Borneti* Wright. The combination of the two forms the *Blodgettia confervoides* Harvey, 1858, p. 48, Pl. XLV. C.

16. C. HOWEI Collins, 1909a, p. 18, Pl. LXXVIII, fig. 1; 1909, p. 349. Tide pools, Gibbet Island, June, 1900, Howe. The short, subsimple filaments arise from a dense mass of prostrate filaments, a character found in no other of our species. Gibbet Island is the type, and so far as known, the only, station for the species; so for the present it may be considered as endemic.

17. C. REPENS (J. Ag.) Harvey, 1846–51, Pl. CCXXXVI; P. B.-A., No. 2071. *Conferva repens* J. G. Agardh, 1842, p. 13; *Aegagropila repens* Kützing, 1854, p. 15, Pl. LXX, fig. II. Gravelly Bay, Jan., Feb., Hervey. A low, densely matted plant of dark color, not however, with prostrate and erect filaments clearly differentiated. The plant from California distributed under this name as P. B.-A., No. 727 has since proved to be *C. trichotoma* (Ag.) Kütz.; the present record is therefore the first for America.

18. C. **frascatii** sp. nov.; P. B.-A., No. 2164. Humilis, 1–2 cm. alta; ramificatione irregulari, inferne plerumque dichotoma, dichotomiis patentibus; superne partim conformi, sed etiam laterali, patente, saepe rectangulari; ramulis ultimis 1–3-cellularibus, prope vel omnino rectangularibus, saepe secundis latere exteriore rami recurvati; cellulis inferne 70–100 μ diam., 2–5 diam. longis, cylindricis; ramulorum 60–80 μ diam., 2–3 diam. longis, leviter inflatis, nodis constrictis; cellula terminali obtusa.

Low, 1–2 cm. high, branching irregular, below mostly dichotomous, with wide forkings; above partly similar, partly lateral, patent, often at a right angle; ultimate ramuli 1–3-celled, nearly or quite at right angles, often secund on the outer side of a recurved branch. Cells below 70–100 μ diam., 2–5 diam. long, cylindrical; in the ramuli 60–80 μ diam., 2–3 diam. long, somewhat swollen with constricted nodes; terminal cell obtuse. In matted tufts in tide pools near Frascati Hotel, Jan. 11, 1914, A. B. Hervey. Type in Collins herb.

Growing in similar places to C. repens, and forming similar matted tufts, but distinct by the smaller dimensions and the lateral, secund, submoniliform ramuli.

*19. C. FRACTA (Fl. Dan.) Kützing, 1843, p. 263; 1854, p. 10, Pl. L; Collins, 1909, p. 353; P. B.-A., No. 2013. *Conferva fracta* Flora Danica, Vol. V., Pl. DCCCCXLVI, 1782. Artificial Reservoir of fresh water near Spanish Rock, Dec., Hervey. Some of the material is in a vigorously growing state; some in a hibernating state, cells with thick walls, dense contents, few branches.

CLADOPHOROPSIS Börgesen.

C. MEMBRANACEA (Ag.) Börgesen, 1905, p. 288, figs. 8–13; 1913, p. 47, fig. 33; Collins, 1909, p. 362; P. B.-A., No. 1866; *Conferva membranacea* Agardh, 1824, p. 120. North Shore, Jan., Tucker's Town, March, Harris Bay, Shelly Bay, April, Hervey; Inlet, May, Hungry Bay, July, Collins. A very common species, forming cushions on rocks, and on and under mangroves; in still pools it is sometimes also in floating masses.

PITHOPHORA Wittrock.

*P. KEWENSIS Wittrock, 1877, p. 52, Pl. I, fig. 8; Pl. II, figs. 1–12; Pl. III, figs. 1–9; Pl. IV, figs. 2–11; Pl. V, figs. 9–10; Collins, 1912, p. 98; P. B.-A., No. 2072. With *Rhizoclonium* etc. in reservoir of fresh water near Spanish Rock, Dec., Hervey.

Anadyomene Lamouroux.

A. stellata (Wulf.) Agardh, 1822, p. 400; Vickers, 1908, p. 21, Pl. XXI; P. B.-A., No. 1906; *A. flabellata* Harvey, 1858, p. 49, Pl. XLIV. A; Alg. Am.-Bor. Exsicc., No. 172; *Ulva stellata* Wulfen in Jacquin, 1786, p. 351. Common in shallow water everywhere about the islands, and dredged down to 18 m.; in quiet places as large, thin fronds, in exposed places masses of short, irregular, densely packed fronds. Apparently equally common at all times of the year. Aug. 11, 1913, in the cave at Agar's Island, young plants were found growing on the rocks between tides, forming a continuous coating, the individual plants not over 1 mm. high. In some individuals the lamina was beginning to form, but most of the plants resembled young *Cladophora*, except that the branching was in one plane. There was a distinct filiform stipe, attached at the base by slender coralloid projections.

Dictyosphaeria Decaisne.

D. favulosa (Ag.) Decaisne, 1842, p. 32; Börgesen, 1913, p. 33, figs. 20–22; Collins, 1909, p. 367, fig. 137; P. B.-A., No. 2015; *Valonia favulosa* Agardh, 1822, p. 432. Harrington Sound, Farlow; South Shore, Jan., Feb., Hervey; Hungry Bay, Tucker's Town, April, Reef, Ely's Harbor, Aug., Collins. Grows both in sheltered and in exposed stations, perhaps more generally in the latter.

Family GOMONTIACEAE.

Gomontia Bornet & Flahault.

G. polyrhiza (Lagerheim) Bornet & Flahault, 1888a, p. 164; 1889, p. CLVIII, Pl. VI–VII; Collins, 1909, p. 370, fig. 135; *Codiolum polyrhizum* Lagerheim, 1885, p. 22. Common in dead shells of mollusks along the shore, giving them a more or less deep grass-green color.

Family VALONIACEAE.

Valonia Ginnani.

1. Fronds bullate, unbranched. 1. V. ventricosa.
1. Fronds branched. 2.
  2. Branches in whorls. 4. V. pachynema.

2. Branches not whorled. 3.
3. Cells spherical, ovoid or pyriform. 2. V. macrophysa.
3. Cells cylindrical to clavate. 3. V. utricularis.

1. V. VENTRICOSA J. G. Agardh, 1886, p. 96; Vickers, 1905, p. 56; 1908, p. 21, Pl. XXIII. A; Collins, 1909, p. 373; Börgesen, 1913, p. 27, fig. 16. July, Kemp; Gravelly Bay, Aug., Collins. At Gravelly Bay this plant was washed ashore; the plants were 1–3 cm. diam., smooth and glassy, spherical or slightly ovoid. Murray states that it is sometimes as large as a hen's egg.

2. V. MACROPHYSA Kützing, 1843, p. 307; 1856, p. 30, Pl. LXXXVII, fig. III; P. B.-A., No. 1867; *V. utricularis* Alg. Am.-Bor. Exsicc., No. 171, not of Agardh. Harrington Sound, Walsingham, Jan., Tucker's Town, Dec., Hervey; pool near Moore's calabash tree, Ducking Stool, April, Ely's Harbor, July, Gravelly Bay, Gibbet Island, Aug., Fairyland, Nov., Collins. Grows usually in dense masses sometimes as large as a man's head; the individual plants are only loosely attached, and are easily separable; under water it usually shows a very brilliant iridescence. The turgor in the living cell is considerable; when the cell is punctured by a dissecting needle, it sends out a fine stream which may reach a distance of a meter or more.

3. V. UTRICULARIS (Roth) Agardh, 1822, p. 431; Collins, 1909, p. 373; *Conferva utricularis* Roth, 1797, p. 160, Pl. I, fig. 1. Dredged in 18 meters, Hamilton Harbor, Dec., Collins.

Forma CRUSTACEA Kuckuck, 1907, p. 180; Börgesen, 1913, p. 30, figs. 17–18; P. B.-A., No. 2074. The typical *V. utricularis* is rather loosely branched, but in forma *crustacea* the cells form a dense mass, and might be mistaken for one of the solid-fronded species of *Dictyosphaeria*, but under the microscope it is easily distinguished by the different manner of attachment of the cells. It has some resemblance to *V. macrophysa*, but the cells are smaller, closely adherent and more elongate. It appears to be a form of shallow water, forming dense masses, as well in the quiet water at Grasmere as on the reefs, always awash, at Ely's Harbor.

4. V. PACHYNEMA (Martens) Weber, 1913, p. 61; *V. confervoides*[8] Harvey, Alg. Ceylon, No. 73; J. G. Agardh, 1886, p. 100; Collins, 1909, p. 373; *Bryopsis pachynema* Martens, 1866, p. 24, Pl. IV, fig. 2. Miss Wilkinson.

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[8] Mme. Weber calls attention to the fact that *Valonia confervoides* was *nomen nudum* until 1886; hence *V. pachynema* has priority.

ERNODESMIS Börgesen.

E. VERTICILLATA (Kütz.) Börgesen, 1912, p. 259, figs. 10–12; 1913, p. 66, figs. 51–54. P. B.-A., No. 1907; *Valonia verticillata* Kützing, 1849, p. 508; Collins, 1909, p. 373. Kemp, April, St. George's, unnamed specimen in herb.; Castle Harbor, Farlow; Harrington Sound, 3–10 dm., June, Howe; cave by Gravelly Bay, April, tidal stream, Hungry Bay, July, Collins. Generally grows in dense masses of crisp fronds, but easily separable.

SIPHONOCLADUS Schmitz.

1. Primary cell long, erect; substance soft.	1. S. tropicus.
1. Primary cell short; substance firm.	2. S. rigidus.

1. S. TROPICUS (Crouan) J. G. Agardh, 1886, p. 105; Börgesen, 1913, p. 61, figs. 44–51; Collins, 1909, p. 374; Vickers, 1908, p. 20, Pl. XVIII; *Apjohnia tropica* Crouan in Mazé & Schramm, 1870–77, p. 105. Harris Bay, in pools, a few individuals only, Feb., Hervey.

2. S. RIGIDUS Howe, 1905, p. 244, Pl. XII, fig. 1; Pl. XIV; Collins, 1909, p. 374, fig. 139; P. B.-A., No. 2169. On flat rock at low water mark, Agar's Island, Dec., Collins.

PETROSIPHON Howe.

P. ADHAERENS Howe, 1905, p. 248, Pl. XV; Collins, 1909, p. 375; P. B.-A., No. 2073. Forming a closely attached crust in pools at Harris Bay, March, Hervey.

STRUVEA Sonder.

S. RAMOSA Dickie, 1874a, p. 316; Murray & Boodle, 1888, p. 280, Pl. XVI, fig. 3; Collins, 1909, p. 377. This species was described from specimens collected by Moseley with the Challenger Expedition; there is no record of it since, either here or elsewhere.

Family DASYCLADACEAE.

Acetabularia Lamouroux.

A. crenulata Lamouroux, 1816, p. 249; Harvey, 1858, p. 40, Pl. XLII. A; Collins, 1909, p. 378, fig. 131; P. B.-A., No. 1908. St. George's, Kemp; Achilles Bay, June, Harrington Sound, Oct., Hervey; Fairyland, July, Harrington Sound, Aug., Collins. Common, at least during summer and autumn, on rocks and pebbles in shallow water, also brought up by dredge from about 5 meters off Spanish Point. Ripe aplanospores were found in plants from Fairyland, distributed as P. B.-A., No. 1908. At this station it covers the bottom in patches many meters square, just below the low water level.

Acicularia d'Archiac.

A. Schenckii (Möb.) Solms, 1895, p. 33, Pl. III, figs. 4, 9, 11, 12, 14, 15; Collins, 1909, p. 380; *Acetabularia Schenckii* Möbius, 1889, p. 318, Pl. X, figs. 8–12. Hungry Bay, in the tidal stream under the mangroves, June, Howe. Resembling *Acetabularia crenulata*, but with disk usually smaller, stipe shorter and stouter. It probably occurs in other stations, but has been overlooked on account of its resemblance to the more common plant.

Neomeris Lamouroux.

N. annulata Dickie, 1874, p. 198; Howe, 1909, p. 87, Pl. I, fig. 2; Collins, 1909, p. 382, fig. 143; P. B.-A., No. 1909; Börgesen, 1913, p. 71, figs. 55–57; *N. Kelleri* Vickers, 1908, p. 28, Pl. XLVI. In shallow water on rock and especially on small stones, and dredged in 18 meters. Faxon; Miss Wilkinson; White Island, June, Howe; Ely's Harbor, July, Harrington Sound, Aug., Collins; Harrington Sound, Oct., Nov., Hervey. Probably to be found in quiet shallow water everywhere in the islands; other species of *Neomeris*, equally common in the West Indies, have not been noticed here.

Dasycladus Agardh.

D. clavaeformis (Roth) Agardh, 1828, p. 16; Collins, 1909, p. 383; P. B.-A., No. 1868; *Conferva clavaeformis* Roth, 1806, p. 315. Cooper's

Island, April, Collins; Pink Bay, Spanish Point, March, Hervey. In habit much like *Batophora Oerstedi var. occidentalis*, but growing in more sheltered places.

BATOPHORA J. G. Agardh.

B. OERSTEDI J. G. Agardh. 1854, p. 108; Collins, 1909, p. 383, fig. 145; Börgesen, 1913, p. 73, fig. 58; P. B.-A., No. 1910. Fairyland, July, with ripe aplanospores, Collins.

Var. OCCIDENTALIS (Harv.) Howe, 1905a, p. 579; Collins, 1909, p. 384; P. B.-A., No. 2016; *Dasycladus occidentalis* Harvey, 1858, p. 38, Pl. XLI. B. Rein; Spanish Point, June, Howe; Shelly Bay. Dec., Hervey. A condensed form, growing in more exposed localities.

FAMILY CODIACEAE.

CODIUM Stackhouse.

1. Prostrate.	1. C. intertextum.
1. Erect.	2.
2. All divisions contracted at base, enlarging upwards.	4. C. isthmocladum.
2. No distinct contractions at base of divisions.	3.
3. Peripheral utricles 100–150 μ diam., exceptionally 200 μ.	2. C. tomentosum.
3. Peripheral utricles rarely under 300 μ.	3. C. decorticatum.

1. **C. intertextum** sp. nov.; P. B.-A., 2018. Fronde prostrata, tereti vel complanata, saxo arcte adhaerente, apicibus autem vulgo liberis; ramis brevibus, irregularibus, stratum subcontinuum formantibus, strato interiore siphonum dense implicatorum strato corticali cincto, utriculorum longorum, cylindricorum vel subclavatorum, apicibus truncatis, subrotundatisve, diam. 70–90 μ; colore atroviridi; substantia subfirma, nec maxime gelatinosa.

Frond prostrate, subterete or flattened, closely adherent to the rock, but with tips usually free; with short, irregular branches, forming an almost continuous coating. Interior layer of densely packed, slender tubes, surrounded by a cortical layer of long, cylindrical or somewhat clavate utricles, with truncate or somewhat rounded ends, 70–90 μ diam. Color dark green, substance rather firm, not specially gelatinous. Forming a continuous belt a few dm. wide on upright or sloping rocks, at low water mark; Harrington Sound, Castle Harbor, etc.

In habit somewhat resembling *C. adhaerens and C. difforme*, but the frond in these is continuous, with margin entire or lobed; in *C. intertextum* the frond is narrow and branching, the branches being so densely set as to make an almost continuous coating, one branch often over another. The utricles are of much the same size and shape as in *C. adhaerens*, but the structure of the latter is dorsiventral, the utricles on the upper side only, the lower, adherent surface consisting of the slender tubes, which in *C. intertextum* form a central layer, surrounded on all sides by the utricles, rarely the middle part of the under surface without the utricles. *C. repens* Crouan, also a prostrate species, has utricles even larger than *C. tomentosum*, of the order of size of *C. decorticatum;* its branching is not as dense as that of *C. intertextum*, being more like that of *C. tomentosum*, but without the erect habit. The utricles vary somewhat in shape and size, as in all species of the genus, but the long, slender shape, the end either sharply truncate or slightly capitate, is distinct from the shape in all other American species except *C. adhaerens*. Type 7070 in Collins herbarium, from Tucker's Town, April 25, 1912. Also from Ely's Harbor, July, Gibbet Island, Sept., Collins; Gravelly Bay, Dec., Hervey. All records of *C. adhaerens* for Bermuda probably belong here.

2. C. TOMENTOSUM (Huds.) Stackhouse, 1795, p. 21, Pl. VII; Harvey, 1846–51, Pl. XCIII; Collins, 1909, p. 388; P. B.-A., No. 1869; *Conferva tomentosa* Hudson, 1762, p. 480. Tucker, No. 4, 1856; Tucker's Town, Farlow; Kemp in herb; Moseley; Buildings Bay, Harrington Sound, Shelly Bay, March, Hervey; Hungry Bay, April, Ely's Harbor, Aug., Collins. Rather common about the islands; sporangia found in May.

3. C. DECORTICATUM (Woodw.) Howe, 1911, p. 494; P. B.-A., No. 2017; *C. elóngatum* Vickers, 1908, p. 22, Pl. XXVII; Collins, 1909, p. 388; *Ulva decorticata* Woodward, 1797, p. 55. Faxon; Miss Peniston; Harrington Sound, April, Aug., St. David's Island, April, Cooper's Island, Gibbet Island, Aug., Collins. Very variable in habit and size, but usually less densely branched than *C. tomentosum*, the branches often quite virgate; usually compressed more or less at or below the axils. But there are often cases when the two species are indistinguishable by external characters; the size of the utricles must then determine; in *C. tomentosum* 100–150 μ diam. rarely to 200 μ; in *C. decorticatum* 300–400 μ diam. rarely to 200 μ. There has

been some question as to whether the distinction between these two species should be based on the size of the utricles, or on the presence or absence of compression; the matter is fully discussed by Bornet, 1892, p. 216. We have adopted the former plan. It must be kept in mind that in actively growing plants or parts of plants, small and immature utricles occur among those of normal size. *C. decorticatum* sometimes grows to a large size; one plant which we found growing below low water mark in Harrington Sound was nearly a meter long and over 10 cm. wide in the expanded part; it was the largest alga we have seen in Bermuda, except possibly some *Sargassum*. It is unfortunate that the rather appropriate name of *elongatum* should have to be replaced by the quite inappropriate *decorticatum*, but as shown by Howe, it seems inevitable.

Var. **clavatum** var. nov. Fronde habitu formam cylindricam *C. decorticati* approximante, sed substantiae firmioris, vix gelatinosa, colore laete viridi; utriculis forma multo variantibus; aliis cylindricis vel leviter clavatis, 80 × 480 μ; aliis 500 μ longis, sursum dilatatis ad caput subsphaericum 145 μ diam.; aliorum inflatione terminali ad 200 μ diam., a parte subcylindrica minus distincta; aliis obcampanulatis, 650 μ longis, 350 μ diam., apice spatio brevi paullo latioribus; aliis turbinatis, 640 μ longis, apice 470 μ diam.; inter omnes, formis intermediis.

Habit that of a rather densely branched cylindrical *C. decorticatum*, but of quite firm substance, hardly gelatinous, color light green. Utricles very variable in form; some cyclindrical or slightly clavate, 80 × 480 μ; some 500 μ long, increasing in size upward to 112 μ, then with a subspherical head 145 μ diam.; in others the capitate swelling up to 200 μ diam., but less sharply marked off from the subcyclindrical part, 120 μ diam.; others inverted bell-shape, 650 μ long, 350 μ diam., somewhat wider for a short space at the truncate top; others turbinate, 640 μ long, 470 μ wide at top; with all intermediate gradations.

The largest utricle observed was 980 μ long, 480 μ diam. The plant is so firm in texture that it does not collapse when taken from the water; but when dried it is thin and papery. Sporangia ovoid, largest at the middle, obtuse at each end; sporangia apparently not mature, 160 × 64 μ, 275 × 105 μ, 280 × 100 μ; mature sporangia, packed with spherical spores about 12 μ diam., 190 × 100 μ, 240 × 120 μ. Type specimen, from stone wall at Inlet, by Frascati Hotel, Dec. 20, 1912, Hervey, No. 7322 in Collins herb. Also at Devonshire Bay, Gravelly Bay, Feb., Causeway, March, Hervey.

4. **C. isthmocladum** Vickers, 1905, p. 57; 1908, p. 23, Pl. XXVIII; Collins, 1909, p. 388. Shelly and Gravelly Bays, March, Hervey. Probably not uncommon, resembling a condensed form of *C. tomentosum,* but with the divisions more or less contracted at the base, gradually increasing in diameter to the next forking. The utricles are larger than in *C. tomentosum,* approaching the size in *C. decorticatum.*

Avrainvillea Decaisne.

1. Filaments distinctly moniliform.	1. A. nigricans.
1. Filaments nearly or quite cylindrical.	2. A. longicaulis.

1. **A. nigricans** Decaisne, 1842, p. 96; Howe, 1907, p. 508, Pl. XXVIII, figs. 8–25; Collins, 1909, p. 390. Walsingham, Feb., Harris Bay, April, Hervey; Inlet, Cooper's Island, Aug., Collins. Very variable, from small, delicate plants to coarse, heavy and unsightly ones.

Var. **fulva** Howe in P. B.-A., No. 1480; Collins, 1909, p. 390; P. B.-A., No. 2171. Stouter, coarser, with less difference between stipe and flabellum; color more yellowish than in the type.

2. **A. longicaulis** (Kütz.) Murray & Boodle, 1889, p. 70, as to name only; Collins, 1909, p. 391; P. B.-A., No. 2170; *Rhipilia longicaulis* Kützing, 1858, p. 13, Pl. XXVIII, fig. 2. Walsingham, Feb., Mangrove Bay, Feb., Harrington Sound, Nov., Inlet, Dec., Hervey; Fairyland, Dec., Collins. Growing in company with *A. nigricans,* from which it is frequently indistinguishable, except that the filaments of the latter show distinctly moniliform on microscopic examination, while those of *A. longicaulis* are nearly or quite cylindrical. The name is a somewhat unfortunate result of following the rules of botanical nomenclature; the authors of the binomial used it for a different plant, *A. nigricans. Rhipilia longicaulis,* from which it derives its specific name, is according to the type specimen the present species, while the description and figure given by Kützing belong better to a third species, *A. sordida* Murray & Boodle. The arguments in favor of the name used here are found in Howe, 1907, p. 509; those in favor of preferring *A. Mazei* Murray & Boodle in Gepp, 1911, p. 27; a later summation will be found in Howe, 1911, p. 133.

Penicillus Lamarck.

1. Surface of stipe smooth.	1. P. capitatus.
1. Surface of stipe rough.	2. P. pyriformis.

1. P. CAPITATUS Lamarck, 1813, p. 299; Harvey, 1858, p. 45, Pl. XLIII. B; Collins, 1909, p. 392; P. B.-A., No. 1911. Kemp, specimen in herb.; Rein; Moseley; Wadsworth, No. 75; Tucker's Town, Farlow; Hungry Bay, June, Howe; Gravelly Bay, March, Mangrove Bay, Feb., Harris Bay, Oct., Nov., Inlet, Dec., Hervey; Cooper's Island, April, Jew's Bay, July, Ely's Harbor, Inlet, Hungry Bay, Aug., Collins. Common practically everywhere in shallow water and dredged down to 10 m.

Forma ELONGATUS (Dcne.) Gepp, 1911, p. 83, figs. 166–167; P. B.-A., No. 1912; *P. elongatus* Decaisne, 1842, p. 97 (reprint). Jew's Bay, July, Harrington Sound, Mangrove Lake, Aug., Collins. A form with long stipe, pyriform head, filaments stouter than in the typical form, in company with which it grows, the two shading into each other.

Forma LAXUS Börgesen, 1913, p. 98, fig. 80. Walsingham, Feb., Hervey. A form with long and slender stipe, head more or less irregular in form, filaments loose and slender. In the specimens which we identify with this form the branching of the stipe is not unusual, each division having a head of the normal shape for this form.

2. P. PYRIFORMIS Gepp, 1905, p. 1, Pl. CCCCLXVIII, fig. 1; Collins, 1909, p. 393; P. B.-A., No. 2075. June, Howe; Feb., Farlow; Harris Bay, Jan., Oct., Dec., Inlet, Dec., Hervey. Often growing with *P. capitatus*, but less common.

UDOTEA Lamouroux.

1.	Whole flabellum with a stony coating.	2. U. flabellum.
1.	Flabellum flexible, individual filaments encrusted.	1. U. conglutinata.

1. U. CONGLUTINATA (Soland.) Lamouroux, 1816, p. 312; Howe, 1909, p. 96, Pl. II, Pl. VIII, figs. 1–13; Collins, 1909, p. 395; P. B.-A., No. 1913; *Corallina conglutinata* Solander in Ellis & Solander, 1786, p. 125, Pl. XXV, fig. 7. Rein; Kemp; South Beach by Paget, Feb., Farlow; Harris Bay, Jan., Feb., March, Nov., Hervey. In tide pools, a small form only; dredged in 10 meters by the Challenger Expedition.

2. U. FLABELLUM (Ell. & Sol.) Howe, 1904, p. 94; Gepp, 1911, p. 131, Pl. III, figs. 26–28; Collins, 1909, p. 395; P. B.-A., No. 1914; *Corallina flabellum* Ellis & Solander, 1786, p. 124, Pl. XXIV. Rein; Kemp; Tucker, No. 23; Walsingham, Farlow; many stations, Hervey,

Collins. Grows practically everywhere in shallow water, varying much in size, texture, outline, etc. Some forms are rounded and entire, wider than broad; some plane, others folded longitudinally; some cuneate and much divided, some consisting of a few linear laciniae from the top of the stipe, the laciniae up to 3 dm. long and less than 1 cm. wide. All pass gradually into each other, so that varietal or form names are useless.

Halimeda Lamouroux.

1. All segments except those bearing branches cylindrical.	4. H. Monile.
1. Most segments ovoid or flattened, not cylindrical.	2.
2. Segments distinctly ribbed.	3. H. tridens.
2. Segments indistinctly or not at all ribbed.	3.
3. Segments strongly calcified, firm, thick.	2. H. simulans.
3. Segments lightly calcified, flexible, thin.	1. H. Tuna.

1. H. Tuna (Ell. & Sol.) Lamouroux, 1812, p. 186; Collins, 1909, p. 400; P. B.-A., No. 1918; *Corallina Tuna* Ellis & Solander, 1786, p. 111, Pl. XX, fig. e. Kemp; Moseley; Walsingham, Farlow; Howe; Harrington Sound, Jan., Inlet, Dec., Harris Bay, Dec., Hervey; cave, Agar's Island, Aug., Hamilton Harbor, dredged in 5 meters. Dec., Collins. Not uncommon, but less frequent than *H. tridens* and *H. Monile.* Our *H. Tuna* seems all to belong to forma *typica* Barton, 1901, p. 13, Pl. I, fig. 1.

2. H. simulans Howe, 1907, p. 503, Pl. XXIX; Collins, 1909, p. 401; P. B.-A., No. 1916. Tucker's Town, Dec., Hervey. Found only in this one locality and in small quantity. Its segments have the outline of those of *H. Tuna,* but are thicker and more calcified.

3. H. tridens (Ell. & Sol.) Lamouroux, 1812, p. 186; Harvey, 1858, p. 24, Pl. XLIV. C; Collins, 1909, p. 398; P. B.-A., No. 1917; *Corallina tridens* Ellis & Solander, 1786, p. 109, Pl. 20, fig. a. Rein; Moseley, as *H. incrassata;* Walsingham, Farlow; many stations, Collins and Hervey, dredged down to 18 meters. Common nearly everywhere and very variable. Of the various varieties and forms to which names have been given, we have

Forma typica (Barton) Collins, 1909, p. 398; *H. incrassata* forma *typica* Barton, 1901, p. 27, Pl. IV, fig. 39. A stout, stony form, with lower joints short, more or less adherent, upper joints three-ribbed or three-lobed.

Forma tripartita (Barton) Collins, 1909, p. 399; *H. incrassata* forma *tripartita* Barton, 1901, p. 27, Pl. IV, fig. 43. A more slender form, less branched, the lower joints longer, the upper joints ending in three cylindrical lobes.

Forma GRACILIS Börgesen, 1913, p. 111, fig. 89. Joints small, subcircular in outline, not strongly calcified.

These forms all pass into each other. Börgesen considers *H. Monile* and *H. simulans* also as forms of this species, and it may be that he is right as to the former, but the differences between these two, and the three forms that we consider to belong to *H. tridens*, are greater than the differences among the latter. Gepp and Börgesen prefer the name *H. incrassata* to *H. tridens;* the case for the former is stated by Börgesen, 1911, p. 136, that for *H. tridens* by Howe, 1907, p. 501.

4. H. Monile (Ell. & Sol.) Lamouroux, 1812, p. 186; Collins, 1909, p. 399; P. B.-A., No. 1915; *H. incrassata* forma *monilis* Barton, 1901, p. 27, Pl. IV, fig. 40; *Corallina monilis* Ellis & Solander, 1786, p. 110, Pl. XX, fig. c. Inlet, Jan., Oct., Dec., Bailey's Bay, Jan., Walsingham, Nov., Tucker's Town, Dec., Hervey; Hungry Bay, April, Collins. Rather common; the forms recognized by Börgesen both occur here.

Forma ROBUSTA Börgesen, 1913, p. 113, fig. 90. Densely branched, the upper joints cylindrical, the lower tripartite and sometimes resembling the upper joints of *H. tridens* forma *tripartita.*

Forma CYLINDRICA Börgesen, 1913, p. 113, fig. 91. Less branched, the joints nearly all cylindrical.

Family BRYOPSIDACEAE.

Bryopsis Lamouroux.

1. Ramuli distichous. 2. B. pennata.
1. Ramuli not distichous. 2.
  2. Main branches virgate, with very slender ramuli. 3. B. Duchassaingii.
  2. Outline pyramidal, branching of several orders, no sharp distinction between branches and ramuli. 1. B. hypnoides.

1. B. HYPNOIDES Lamouroux, 1809, p. 333; 1809b, p. 135, Pl. I, fig. 2, a & b; Collins, 1909, p. 403. Harrington Sound, Jan., Feb., April, Walsingham, March, Hervey; Kemp, May, as *B. plumosa,* in part; cave by Gravelly Bay, April, Collins.

Forma PROLONGATA J. G. Agardh, 1886, p. 28; P. B.-A., No. 1870; *B. hypnoides* Harvey, 1846–51, Pl. CXIX. Harrington Sound, May, Dec., Collins; Old Ferry, April, Hervey.

2. B. Duchassaingii J. G. Agardh, 1854, p. 107; Collins, 1909,

p. 403; *Trichosolen antillarum* Montagne, 1860, p. 171, Pl. XI. C. Kemp; Harrington Sound, March, Hervey.

Var. **filicina** var. nov. Frondis circumscriptione late vel anguste lanceolata; axi primario non diviso; axibus secundariis approximatis, aequidistantibus, saepe oppositis, a basi ramulis tenuissimis aequilongis dense obsitis.

Outline of frond broadly to narrowly lanceolate; main axis not divided; secondary axes closely and uniformly set, often opposite, densely beset from the base with very fine ramuli of equal length. Near Flatts bridge, Feb., Hervey. Type in Collins herb.

The habit of this variety is strikingly different from that of typical *B. Duchassaingii*, and the very regular pinnate branching makes it a beautiful object; but in a genus where there is so much variation within each species, it is hardly safe to consider this a distinct species.

3. B. PENNATA Lamouroux, 1809, p. 133; 1809b, p. 134, Pl. III, fig. 1; Collins, 1909, p. 405; P. B.-A., No. 1871. Rein, as *B. plumosa;* Kemp, as *B. plumosa*, in part, *B. hypnoides*, in part. In Collins, 1909, *B. pennata*, *B. Leprieurii* and *B. Harveyana* were kept distinct, chiefly on the judgment of Miss Vickers, who was familiar with them at Barbados. Since then we have examined some 200 specimens of *Bryopsis* of Miss Vickers' collecting, and some hundreds of specimens from Bermuda, and we have come to the conclusion that while typical examples of these three are quite distinct, intermediate forms are more common, and specific distinction is impracticable. So far we agree with Börgesen, 1911, p. 145, and 1913, p. 117, but we cannot agree with him in placing them all under *B. plumosa* (Huds.) Ag. The normal form of *B. pennata* seems to be a long, simple rachis, with short, distichous ramuli of uniform length, giving a linear outline to the frond. In *B. plumosa* the rachis bears lateral branches, increasing in length from the apex to the base, so as to give a triangular outline, usually broadly triangular, to the frond. Each of the branches has a similar triangular outline. There is much variation in luxuriance of branching, but in examining a considerable series of *B. plumosa* from northern Europe and America, to the Mediterranean on one side, to North Carolina on the other, we have seen nothing like the linear form. Among the abundant material from Barbados and Bermuda we have found no plants with repeated triangular outline of the frond and its divisions. We recognize the same varieties as Börgesen, but place them under *B. pennata*, the oldest name for the distinctly linear forms. The species and its varieties are to be found almost everywhere in the islands, but one must expect more intermediate than typical forms; moreover old plants become denuded, and present many puzzles.

Var. **secunda** (Harv.) comb. nov.; *B. plumosa* var. *secunda* Harvey, 1858, p. 31, Pl. XLV. A, figs. 1–3; *B. Harveyana* Collins, 1909, p. 405. This variety shows a certain dorsiventral arrangement, the ramuli on both edges of the rachis curving towards each other on one side.

Var. **Leprieurii** (Kütz.) comb. nov.; *B. Leprieurii* Kützing, 1849, p. 490; 1856, p. 27, Pl. LXXV, fig. 2; Collins, 1909, p. 404. In this variety the ramuli are in short secund series, separated by short vacant spaces.

Family DERBESIACEAE.

Derbesia Solier.

1. Filaments 100–600 μ diam. 3. D. Lamourouxii.
1. Filaments less than 100 μ diam. 2.
  2. Filaments 40–50 μ diam., dichotomously branched. 1. D. vaucheriaeformis.
  2. Filaments 50–70 μ diam., simple or with short lateral branches. 2. D. marina.

1. D. VAUCHERIAEFORMIS (Harv.) J. G. Agardh, 1886, p. 34; Collins, 1909, p. 406; *D. tenuissima* Farlow, 1881, p. 60, Pl. IV, fig. 4; *Chlorodesmis vaucheriaeformis* Harvey, 1858, p. 30, Pl. XL. D. On *Dictyopteris Justii*, Gravelly Bay, Aug., Collins. With sporangia.

2. D. MARINA (Lyng.) Kjellman, 1883, p. 16; Collins, 1909, p. 407; *Vaucheria marina* Lyngbye, 1819, p. 79, Pl. XXII. On *Acanthophora spicifera*, Hungry Bay, May, Collins. With sporangia.

3. D. LAMOUROUXII (J. Ag.) Solier, 1847, p. 162, Pl. IX, figs. 18–30; Collins, 1909, p. 407; P. B.-A., No. 2168; *Bryopsis Balbisiana* var. *Lamourouxii* J. G. Agardh, 1842, p. 18. Castle Harbor, near landing at Tucker's Town, March, Hervey. The fronds are much stouter than in the two other species of the genus, sometimes simple, sometimes with a few irregular tufts of ramuli. Old and denuded plants of *Bryopsis* have some resemblance to it, but always show the scars of fallen ramuli.

Family CAULERPACEAE.

Caulerpa Lamouroux.

1. Stolon and fronds filiform, without distinct ramuli. 1. C. fastigiata.
1. Stolon and fronds different in character. 2.
  2. Fronds very slender, ramuli whorled, near the summit. 3.
  2. Fronds stouter, ramuli not in distinct whorls. 4.

3. Fronds not over 1 cm. high, stolon and base of frond hairy. 2. C. pusilla.
3. Fronds to 5 cm. high, hairs wanting or few. 3. C. verticillata.
  4. Fronds flat or with ramuli in one plane. 5.
  4. Ramuli not in one plane. 8.
5. Frond flat, entire or with proliferations. 4. C. prolifera.
5. Frond pinnate. 6.
  6. Pinnules flat. 5. C. crassifolia.
  6. Pinnules cylindrical or compressed. 7.
7. Pinnules narrowed at base and tapering to tip. 6. C. taxifolia.
7. Pinnules at base somewhat larger than at the curved and mucronate tip. 7. C. sertularioides.
  8. Ramuli peltate. 8. C. peltata.
  8. Ramuli not peltate. 9.
9. Ramuli varying from long-clavate to spherical-pedicellate. 9. C. racemosa.
9. Ramuli short, of various form, the lowest always rostriform. 10. C. cupressoides.

1. C. FASTIGIATA Montagne, 1838, p. 19, Pl. II, fig. 3; Collins, 1909, p. 411. Dingle Bay, March, Hervey; Hungry Bay, April, Collins. Fine, Vaucheria-like tufts or mats on mangroves and other objects near low water mark. The Hungry Bay material seems to be the floating form known as var. *confervoides* Crouan.

2. C. PUSILLA (Kütz.) J. G. Agardh, 1872, p. 6; Weber, 1898, p. 266, Pl. XX, fig. 6; Vickers, 1908, p. 25, Pl. XXXVIII; Collins, 1909, p. 412; P. B.-A., No. 2019. *Stephanocoelium pusillum* Kützing, 1847, p. 54. Tide pool, Harris Bay, Oct., Nov., Hervey. The branching stolon creeps over the loose sand etc., on the bottom of the pool, forming with other small algae a thin but firm turf, which has to be forcibly torn apart to show the character of the plant. The ramuli are in two or three whorls; in the Bermuda plants these whorls are more closely set than in the forms figured by Mme. Weber and Miss Vickers, and can often be distinguished only by dissection.

3. C. VERTICILLATA J. G. Agardh, 1848, p. 6; Weber, 1898, p. 267, Pl. XX, figs. 7–10; Collins, 1909, p. 412; Börgesen, 1907, p. 355, figs. 1–3; 1913, p. 121, figs. 95, 96. St. George's, April, Hervey.

4. C. PROLIFERA (Forsk.) Lamouroux, 1809, p. 332; Weber, 1898, p. 278, Pl. XXII, fig. 1; Collins, 1909, p. 413; P. B.-A., No. 1872; *Fucus proliferus* Forskål, 1775, p. 163. Rein; Kemp; Walsingham, Farlow; Walsingham, April, Hervey; Pool by Moore's calabash tree, April, Somerset Bridge, July, Ely's reef, July, Collins. Typical form, passing into

Forma OBOVATA J. G. Agardh, 1872, p. 11; Börgesen, 1907, p. 359, fig. 4; 1913, p. 127, fig. 100; Collins, 1909, p. 413; with broad, little proliferous fronds.

Forma ZOSTERIFOLIA Börgesen, 1907, p. 359, fig. 6; 1913, p. 127, fig. 101; Collins, 1909, p. 413; with narrow, proliferous fronds; Fairyland, Dec., Collins.

5. C. CRASSIFOLIA (Ag.) J. G. Agardh, 1872, p. 13. Typical *C. crassifolia* has not been found here; forma *laxior* is common, and is apparently a well marked endemic form, not having been reported elsewhere; forma *mexicana* is the common form of Florida and the West Indies, and though not rare in Bermuda is less common than forma *laxior*.

Forma LAXIOR (Weber) Collins, 1909, p. 413; P. B.-A., No. 1919; *C. pinnata* forma *laxior* Weber, 1898, p. 291; *C. crassifolia* var. *mexicana* Alg. Am. Bor. Exsicc., No. 170. Walsingham, April, Hervey; Hungry Bay, Tuckertown, Gravelly Bay, Pool by Moore's calabash tree, Cliff pool, April, Harrington Sound, May, Collins.

Forma MEXICANA (Sond.) J. G. Agardh, 1872, p. 13; Collins, 1909, p. 413; *C. mexicana* Sonder in Kützing, 1849, p. 496; Harvey, 1858, p. 16, Pl. XXXVII. A; Gibbet Island, Bailey's Bay, Jan., Hervey.

The form from Cliff Pool deserves special notice; Cliff Pool is a name we have used for a small but deep pool, near the SW. corner of Harrington Sound, between Tucker's Bay and Green Bay. It has a steep cliff on the side towards the sea; on the other side it is near the Sound, but separated from it by land considerably above its level. It evidently has underground connection with the Sound, the water rising and falling somewhat with the tide. On the surface of this pool, in April and May, 1912, was a floating mass of algae, chiefly *C. crassifolia*, *C. racemosa* and *C. sertularioides*. The stolons floated on the surface, the fronds extending beside them, the tapering rhizoids hanging straight down, sometimes reaching a length of 2 dm., reminding one of the roots of a *Lemna* or *Spirodela*, on a larger scale. Börgesen, 1907, p. 344, classifies the Caulerpas under three types. (1) The epiphytic or mud-collecting Cauperpas. (2) The sand and mud Caulerpas. (3) Rock and coral-reef Caulerpas. These three types are represented in Bermuda, and we can now add a fourth, the floating Caulerpas. Evidently this form can occur only at a station with considerable depth of water, not reached by surf, sheltered from winds, and with no current. Specimens collected here in May have been distributed as P. B.-A., Nos. 1873 and 2021. The station was revisited in August, 1913, but only a few bleached individuals were found; apparently the plants could not endure the intense heat of the midsummer sun.

6. C. TAXIFOLIA (Vahl) Agardh, 1822, p. 435; Weber, 1898, p. 292; Börgesen, 1907, p. 363, figs. 9–10; 1913, p. 131, figs. 104–105; Collins, 1909, p. 414; *Fucus taxifolius* Vahl, 1802, p. 36. Farlow; Walsingham, a single plant, Hervey. Apparently rare, but may have been mistaken for the commoner *C. crassifolia* or *C. sertularioides*, from both of which it can be distinguished by the opposite, sickle-shaped, narrow pinnules, with contracted base.

7. C. SERTULARIOIDES (Gmel.) Howe, 1905a, p. 576; Collins, 1909, p. 414; *Fucus sertularioides* Gmelin, 1768, p. 151, Pl. XV, fig. 4.

Forma LONGISETA (J. Ag.) Svedelius, 1906, p. 114, fig. 10; Collins, 1909, p. 415; P. B.-A., No. 1873; *C. plumaris* forma *longiseta* Weber, 1898, p. 295. Harrington Sound, Oct., Hervey; Cliff Pool, April, Collins.

Forma BREVIPES (J. Ag.) Svedelius, 1906, p. 114, fig. 7; Collins, 1909, p. 415; *C. plumaris* forma *brevipes* Weber, 1898, p. 294. Walsingham, March, Hervey; Ely's Harbor, July, Collins.

8. C. PELTATA (Turn.) Lamouroux, 1809, p. 332; 1809c, p. 145, Pl. III, fig. 2; Weber, 1898, p. 373, Pl. XXXI, figs. 9–11; Collins, 1909, p. 421; *Fucus chemnitzia* var. *peltatus* Turner, 1819, p. 8, Pl. CC. Faxon, a single quite typical specimen; Bethel's Island, Dec., Collins.

9. C. RACEMOSA (Forsk.) J. G. Agardh, 1872, p. 35; Weber, 1898, p. 357, Pl. XXXI, figs. 5–8; XXXII, figs. 1–7; Collins, 1909, p. 419; *Fucus racemosus* Forskäl, 1775, p. 191. A very variable species, with no acknowledged typical form, apart from the many forms and varieties into which it has been divided. It is uncertain to which of these should be referred the *C. clavifera* of Rein and Moseley.

Var. CLAVIFERA (Turn.) Weber, 1898, p. 361: Vickers, 1908, p. 28, Pl. XLV; Collins, 1909, p. 420; *Fucus clavifer* Turner, 1808, Pl. LXXVII. Harrington Sound, March, Wadsworth, No. 71; Hamilton, Farlow; these are the only records of the typical form of this variety, but forms between this and vars. *uvifera* and *lactevirens* are not uncommon.

Var. UVIFERA (Turn.) J. G. Agardh, 1872, p. 35; Weber, 1898, p. 363, Pl. XXXIII, figs. 6–7; Collins, 1909, p. 420; P. B.-A., No. 2022. *Fucus uvifer* Turner, 1819, Pl. CCXXX; Gravelly Bay, Feb., Hervey.

Var. OCCIDENTALIS (J. Ag.) Börgesen, 1907, p. 379, figs. 28–29; 1913, p. 152, fig. 124; Collins, 1909, p. 420; P. B.-A., No. 2021. *C. chemnitzia* var. *occidentalis* J. G. Agardh, 1872, p. 37; Walsingham, Jan., March, Tucker's Town, Feb., Dec., Hervey; Cliff Pool, Hungry Bay, April, Hamilton Harbor, dredged down to 18 meters, Dec., Collins. Agrees well with Börgesen's description and figures, and with the plant distributed as W. N. & L., No. 1586. The Cliff Pool plants have mostly more distant ramuli, but some individuals are quite typical. At Hungry Bay a form was found in which the ramuli were produced on one side of the frond only; not secund in the usual sense, as they were not in a single series, but were placed, apparently irregularly, on one semi-cylinder of the axis, the other being naked.

Var. LAETEVIRENS (Mont.) Weber, 1898, p. 366, Pl. XXXIII, figs. 8, 16–22; Börgesen, 1907, p. 386, fig. 30; 1913, p. 154, fig. 125; Collins, 1909, p. 420; P. B.-A., No. 2020. *C. laetevirens* Montagne, 1842, p. 16. Kemp, in herb.; Wadsworth, No. 70; Walsingham, March, Hervey; Tucker's Town, April, Cooper's Island, Aug., Collins.

10. C. CUPRESSOIDES (Vahl) Agardh, 1822, p. 441; Weber, 1898, p. 323; Collins, 1909, p. 416; *Fucus cupressoides* Vahl, 1802, p. 29. A species containing many forms, all intergrading, once held to be distinct species.

Var. TYPICA Weber, 1898, p. 326; Börgesen, 1907, p. 368, figs. 14–16; 1913, p. 137, figs. 109–111. South Beach, Paget, Farlow.

Var. MAMILLOSA (Mont.) Weber, 1898, p. 332, Pl. XXXVIII, figs. 2–7; Collins, 1909, p. 417; Alg. Am.-Bor. Exsicc., No. 96; P. B.-A., No. 1920; *Caulerpa mamillosa* Montagne, 1842, p. 13. Outer reef, Ely's Harbor, July, Somerset Bridge, July, Gravelly Bay, Aug., Collins. At Gravelly Bay it grew exposed to the waves, the stolon adhering firmly to the rock and covered with sand, so that only the short fronds were visible, often only the tips.

Var. ERICIFOLIA (Turn.) Weber, 1898, p. 335; Collins, 1909, p. 417; *Fucus ericifolius* Turner, 1808, p. 124, Pl. LVI, "found at Bermuda Islands, Herb. Banks." Kemp, in herb. as *C. ericifolia;* Gravelly Bay, Aug., Collins. A few plants at Gravelly Bay, among var. *mamillosa,* distinguished by the cylindrical ramuli.

C. Ashmeadii Harvey, is recorded in Collins, 1909, p. 414, as occurring at Bermuda. We have not been able to confirm this record, and as we have not ourselves found this species, we do not include it in the present work.

FAMILY VAUCHERIACEAE.

VAUCHERIA DC.

*V. SPHAEROSPORA Nordstedt, 1878, p. 177, Pl. II, figs. 7–8; Collins, 1909, p. 429. In "Millbrook" Dec., Collins, with oogonia and antheridia. This species has been found in Greenland, Denmark, Sweden and Great Britain, and also in Uruguay. The Bermuda plant is dioecious, agreeing in that respect with the South American form; in Europe the species is monoecious. Another *Vaucheria* was found at Hungry Bay, Collins, but being sterile could not be specifically determined.

DICHOTOMOSIPHON Ernst.

D. PUSILLUS Collins, 1909, p. 431; P. B.-A., No. 2023. Bailey's Bay, Jan., Harrington Sound, March, Inlet, March, Hervey; Shelly Bay, Hungry Bay, April, Collins. Apparently common, forming dark green or almost black mats on rocks, Udotea etc., or loose floating felts. At Bailey's Bay it was found with filaments 50 μ diam.; the normal diam. does not exceed 30 μ. In the material from Harrington Sound, the contents of the filaments is often divided into sections, approximately as long as their diameter, separated by a narrow transparent space in a plane at right angles with the axis of the filament. This may be preliminary to the formation of spores of some sort, but no more advanced stage was seen.

FAMILY CHARACEAE.

CHARA Agardh.

*C. GYMNOPUS var. BERTEROI A. Braun, 1882, p. 195. Pembroke Marshes, Jan., Farlow. The specimen in the Farlow herbarium was characterized by Nordstedt, in litt., as "forma tenuior" which we understand to be merely descriptive, not a name.

Class **PHAEOPHYCEAE.**

Family ECTOCARPACEAE.

Pylaiella Bory.

P. fulvescens (Schousboe) Bornet, 1889, p. 5, Pl. I; P. B.-A., No. 2076; *Conferva fulvescens* Schousboe ms ex Bornet. On sand-covered rocks by lighthouse, St. David's Island, May, 1913, Hervey. The plant agrees fully with Bornet's figure as to form and dimension of horizontal filaments and sporangia; the erect filaments are in part simple, as figured by Bornet, in part like those figured by Sauvageau, 1896a, fig. 1, being recurved near the tips, and bearing numerous longer or shorter branches, mostly on the outer side of the curve. The unilocular sporangia are rare, but well developed. *P. Hooperi*, Barbados, Miss Vickers, seems hardly distinct. In comparing the description of *P. fulvescens* by Bornet with that of *Pylaiella* sp. (*Ectocarpus Hooperi* Crouan) on the following page, the chief distinctive character of the latter would seem to be the Rhizoclonium-like ramuli near the base; such ramuli were occasionally seen in the Bermuda plant, but were not at all abundant.

Ectocarpus Lyngbye.

1. Lower part of frond endophytic. 2.
1. Not endophytic. 3.
   2. Only slightly endophytic, in Dictyopteris Justii; largely free; plurilocular sporangia cylindrical. 8. E. luteolus.
   2. Mostly endophytic, in Halymenia; plurilocular sporangia ovoid. 9. E. parasiticus.
3. Erect filaments arising from prostrate, branching filaments. 4.
3. No distinct prostrate filaments. 5.
   4. Erect filaments with plurilocular sporangia near base, no other branching. 7. E. elachistaeformis.
   4. Erect filaments freely branched, bearing sporangia throughout. 9.
5. Plurilocular sporangia seriate on upper side of branches, near base. 6.
5. Plurilocular sporangia variously placed, not seriate. 8.
   6. Plurilocular sporangia cylindrical. 3. E. Mitchellae.
   6. Plurilocular sporangia ovoid to conical. 7.

7. Branching irregular, branches patent. 4. E. coniferus.
7. Branches subsecund, ramuli long, pectinate. 5. E. Sandrianus.
    8. Plurilocular sporangia fusiform, unilocular unknown. 1. E. confervoides.
    8. Plurilocular sporangia short-conical, unilocular ovoid or subspherical. 2. E. siliculosus forma arctus.
9. Plurilocular sporangia variable, always blunt or truncate. 6. E. Duchassaingianus.
9. Plurilocular sporangia acute. 10. E. Rallsiae.

1. E. CONFERVOIDES (Roth) Le Jolis, 1863, p. 75; Kuckuck, 1891, p. 19, fig. 3; *Ceramium confervoides* Roth, 1797, p. 151. Floating, Gibbet Island, March, Hervey. Somewhat variable, but mostly of the typical form.

2. E. SILICULOSUS (Dillw.) Lyng. forma ARCTUS (Kütz.) Kuckuck, 1891, p. 18; P. B.-A., No. 1922; *Ectocarpus arctus* Kützing, 1843, p. 289; *Corticularia arcta* Kützing, 1855, p. 23, Pl. LXXX, fig. II. On sand covered rocks, below low water mark, Gibbet Island, March, Harris Bay, April, Hervey; floating, Tucker's Town, April, Harrington Sound, May, Collins. *E. acanthoides* Vickers, Barbados, No. 95, seems to be the same plant. We have not found in Bermuda the typical form of *E. siliculosus,* which is common on both sides of the North Atlantic.

3. E. MITCHELLAE Harvey, 1852, p. 142, Pl. XII. G; P. B.-A., No. 1921; *E. virescens* Thuret in Sauvageau, 1896, p. 18 of reprint. Harris Bay, Heron Bay, Jan., St. David's Island, Feb., Harrington Sound, Shelly Bay, March, Hervey; Shelly Bay, Harrington Sound, Cooper's Island, April, Collins. A common species, growing on corals, larger algae, aquatic phanerogams, and on submerged twigs of live Tamarisk. Plurilocular fruit apparently always abundant, megasporangia and meiosporangia in about equal numbers. The former have not been recorded for the Atlantic coast of North America, where the species is common, but were found in California, and distributed as P. B.-A., No. 671. When growing on any hard substance, rhizoidal growth is usually insignificant; on *Castagnea, Helminthocladia* etc., the rhizoids are strongly developed, penetrating well into the tissue of the host.

4. E. CONIFERUS Börgesen, 1914, p. 164, figs. 131–132. Shelly Bay, April. Hervey, among *E. Mitchellae.* This species was quite recently described from the Danish West Indies, and its occurrence at Bermuda is of interest, indicating that it may be found at other stations in the Atlantic.

5. E. Sandrianus Zanardini, 1843, p. 41; 1865, p. 143, Pl. LXXIV. B; *E. elegans* Thuret in Le Jolis, 1863, p. 77, Pl. II, fig. 1–2; not of Menegh. Shelly Bay, Jan., St. David's Island, Feb., Hervey; with plurilocular sporangia. In both cases mixed with other species of *Ectocarpus;* this mixture of species of *Ectocarpus* is quite common and sometimes perplexing. It is the rule rather than the exception.

6. E. Duchassaingianus Grunow, 1867, p. 45, Pl. IV, fig. 1; Vickers, 1905, p. 59; 1908, Pl. XXVII; Börgesen, 1914, p. 159, figs. 127–128; P. B.-A., No. 2077. Major's Bay, March, Hervey. On sticks and twigs, outlet of aquarium, Agar's Island, Aug., Collins. The Major's Bay plant agrees with Börgesen's description and figures, and with a specimen of Miss Vickers, Barbados, No. 89. The plant from the aquarium outlet differs in the absence of hairs, and in the greater variability of form of the plurilocular sporangia. These are often exactly like Börgesen's figures, but in other instances the cylindrical or clavate body of the sporangium has a shortly acuminate or subulate apex; the same occurs in Miss Vickers specimen. Unilocular sporangia were not seen. The cells were all very densely packed, and it was only in the youngest that the irregularly rounded disks of the chromatophores could be seen. Though there were no hairs, the branches often ended in a long simple filament, 10–14 μ diam., with longer cells than in the rest of the plant, but all were well supplied with chromatophores. The sporangia were sometimes sessile, oftener on a short pedicel, occasionally terminating a branch, as shown in Börgesen's fig. 128e. The cell bearing a sporangium was usually distinctly shorter than the adjacent cells, as in *E. indicus* Sonder, as noted by Mme. Weber, 1913, p. 129, fig. 34. We are inclined to agree with Börgesen that *E. Duchassiangus* may be merely a form of *E. indicus,* but for the present it seems better to retain the former name. The station where this plant occurred is a peculiar one; the salt water outlet of the aquarium is well up in the rock at the shore of the island; the water runs down into the sea, stalks of grass and other objects reached by it being covered by a dense coating of various kinds of algae, *Enteromorpha* predominating, but also other Chlorophyceae and several Myxophyceae; the variations of this material from the type may be due in some way to the exceptional conditions.

7. E. elachistaeformis Heydrich, 1892, p. 470, Pl. XXV, fig. 14; Börgesen, 1914, p. 174, fig. 137. On *Codium decorticatum,* Cooper's Island, Aug., on *Galaxaura squalida* & *Helminthodadia Calvadosii,* St. David's Island, April, Collins. The form reported by Börgesen

differs somewhat from the typical, but not enough to raise any question as to identity. Our form comes nearer to the type from New Guinea. The only marked difference is in the basal portion of the plant growing on *Codium*. When growing on *Sargassum* it formed a more or less definite basal layer, from which short rhizoids issued, entering the host. On the *Codium* there is no definite basal layer, but a compact bundle of irregular rhizoidal filaments, narrower than the assimilating filaments, with few chromatophores, and cells up to 10 diam. long. The lower ends of these rhizoids separate more or less, and spread among the utricles of the host. This difference is explainable by the difference in structure of the hosts. On the *Galaxaura* the rhizoids are less conspicuous. Plurilocular sporangia, similar to those figured by Heydrich, were abundant.

8. E. LUTEOLUS Sauvageau, 1892, p. 25, Pl. II, figs. 14–19. On *Dictyopteris Justii*, South Shore, Aug., Collins. The lower part of the frond inhabits the tissue of the host; the upper part forms a fine down on the surface.

9. E. PARASITICUS Sauvageau, 1892, p. 28, Pl. III, figs. 20–23; *Streblonema parasiticum* (Sauv.) De Toni, 1895, p. 575. In *Halymenia pseudofloresia*, Jan., Hervey. Mostly endophytic; the plants from Maine, distributed as P. B.-A., No. 1337, were chiefly external, the difference being probably due to the firmer tissue of the host in the latter case, *Cystoclonium purpurascens*.

10. E. RALLSIAE Vickers, 1905, p. 59; 1908, Pl. XXXII; Börgesen, 1914, p. 169, fig. 133; P. B.-A., No. 2172. On *Helminthocladia calvadosii*, Old Ferry, April, Hervey. The main filaments are occasionally stouter than in the Barbados and St. Thomas material, up to 40 μ diam., but usually not over 30 μ, in lesser divisions down to 20 μ, in hairs to 10 μ. There is a system of descending filaments, irregular and twisted, but otherwise like the erect filaments, extending for quite a distance in the tissues of the host; plurilocular sporangia agree in form, dimensions and position with Börgesen's figure.

STREBLONEMA Derbès & Solier.

S. SPHAERICUM Derbès & Solier in Castagne, 1851, p. 100; Sauvageau, 1897, p. 18, figs. 2–3 (of reprint); Kuckuck, 1899, p. 28, figs. 6–7. In *Castagnea Zosterae*, Cooper's Island, April, Collins. With uni- and plurilocular sporangia; generally in company with *Myriotrichia*, which it much resembles.

Ascocyclus Magnus.

A. **orbicularis** (J. Ag.) Magnus, 1874, p. 73; P. B.-A., No. 1878; *Myrionema orbiculare* J. G. Agardh, 1848, p. 48. On marine phanerogams in shallow water, Cooper's Island, April, Collins. Probably elsewhere, but easily overlooked.

Family SPHACELARIACEAE.

Sphacelaria Lyngbye.

1. Propagula with broad body. 2.
1. Propagula slender, branching. 3.
  2. Filaments mostly 30–40 μ diam.; lateral cell of propagulum not divided. 3. S. tribuloides.
  2. Filaments mostly 55–75 μ diam.; lateral cell of propagulum divided into two. 4. S. novae-hollandiae.
3. Propagulum with three rays from summit of pedicel. 2. S. fusca.
3. Propagulum with two rays from summit of pedicel. 1. S. furcigera.

1. S. **furcigera** Kützing, 1855, p. 27, Pl. CX; Sauvageau, 1901,[9] p. 145, fig. 35. On small spider crab, Hungry Bay, July, on floating *Turbinaria*, Dec., Collins; with propagula.

2. S. **fusca** (Huds.) Agardh, 1828, p. 28; Sauvageau, 1902, p. 206, fig. 43; *Conferva fusca* Hudson, 1798, p. 602. Spanish Rock, April, Hervey, with propagula.

3. S. **tribuloides** Meneghini, 1840, p. 2; Sauvageau, 1901, p. 123, figs. 28–29; P. B.-A., No. 1923. Not uncommon in shallow rock pools and on various submerged substances. In pools, South Shore, Farlow; Harris Bay, Feb., March, Dec., Gravelly Bay, Jan., Hervey; on *Galaxaura*, St. David's, April, Collins. Found once on twigs of Tamarisk that drooped into the water of Harrington Sound. Propagula common; no sporangia seen.

4. S. **novae-hollandiae** Sonder, 1845, p. 50; Sauvageau, 1901, p. 137, fig. 33. In small quantity, among *S. tribuloides*, Spanish Rock,

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[9] In references to this work, the page given is that of the completed and separate issue; the date, however, is that of the original publication in the Journal de Botanique.

Harris Bay, March, Hervey. The species is a native of Australia, but has been found at Martinique and at Barbados; in both these places it was in company with *S. tribuloides*, as at Bermuda. It is a stouter plant than the latter, and the technical difference, though not striking, seems to be constant.

FAMILY ENCOELIACEAE.

COLPOMENIA Derbès & Solier.

C. SINUOSA (Roth) Derbès & Solier, 1856, p. 11, Pl. XXII, figs. 18–20; Börgesen, 1914, p. 176, fig. 138; P. B.-A., No. 2024; *Ulva sinuosa* Roth, 1806, p. 327, Pl. XII, fig. 2. Rein; Moseley; Kemp, as *Asperococcus sinuosus;* Gibbet Island, Tucker's Town, Gravelly Bay, Harrington Sound, Feb., Hungry Bay, April, Hervey. Very common from Feb. to April, disappearing entirely in July and August, and at least the first part of September. On exposed shores it forms a nearly continuous coating, firmly adherent to the rock; in quiet water, such as the tidal stream at Hungry Bay, it takes the form of subspherical vesicles, up to 20 cm. diam.

HYDROCLATHRUS Bory.

H. CANCELLATUS Bory, 1825, p. 419; Vickers, 1908, Pl. XXIII; Börgesen, 1914, p. 177, fig. 139; P. B.-A., No. 2078. Spanish Rock, March, April, Hervey. Apparently not common.

SCYTOSIPHON Agardh.

S. LOMENTARIA (Lyng.) J. G. Agardh, 1848, p. 126; P. B.-A., No. 2079; *Chorda Lomentaria* Lyngbye, 1819, p. 74, Pl. XVIII. E. Inlet, Feb., Dec., Bailey's Bay, Jan., Mangrove Bay, Feb., Hervey. Appears to be a plant of winter and early spring, varying in different years as to date of appearance, in some years not appearing at all at a station where it was plenty the year before. It is a rapid grower, and disappears soon after maturity.

ROSENVINGIA Börgesen.

R. INTRICATA (J. Ag.) Börgesen, 1914, p. 182; P. B.-A., No. 2173; *Asperococcus intricatus* J. G. Agardh, 1847, p. 7; *Striaria intricata* Vickers, 1905, p. 59; 1908, p. 41, Pl. XXIV. Harris Bay, Feb., Hervey, with plurilocular sporangia.

FAMILY MYRIOTRICHIACEAE.

MYRIOTRICHIA Harvey.

M. REPENS Hauck, 1879, p. 22; Kuckuck, 1899, p. 21, Pl. III (of reprint); P. B.-A., No. 2025; *Dichosporangium repens* Hauck, 1885, p. 339, fig. 141. In fronds of *Castagnea Zosterae*, Cooper's Island, April, Collins. The creeping filaments bear abundant unilocular sporangia; the erect filaments bear each a terminal cluster of plurilocular sporangia; no unilocular sporangia were seen on the erect filaments. *Streblonema sphaericum*, with both kinds of sporangia, accompanies the *Myriotrichia*. As pointed out by Kuckuck, it is practically impossible to distinguish the two species when both bear only unilocular sporangia, as is often the case; the presence of erect filaments in *Myriotrichia* and their absence in *Streblonema* is the only distinguishing character.

FAMILY MESOGLOIACEAE.

CASTAGNEA Derbès & Solier.

C. ZOSTERAE (Mohr) Thuret, fide Börgesen, 1914, p. 184, figs. 144–145; *Castagnea mediterranea* P. B.-A., No. 1879. Kemp, as *Mesogloia vermicularis, M. Griffithsiana* and *M. Chordariae;* Castle Harbor, Bailey's Bay, March, Wadsworth; Shelly Bay, Jan., Castle Harbor, Feb., Hervey; Cooper's Island, April, Collins. As this plant seems to be the same as that from the Danish West Indies, we provisionally give the same name used by Börgesen. It was distributed by us as *C. mediterranea* (Kütz.) Bornet, but is not *Cladosiphon mediterraneus* Kützing, as shown by comparison with an authentic specimen of the latter, for which we are indebted to the kindness of

Dr. M. A. Howe. It is certainly not *C. Zosterae* Farlow, 1881, p. 86, Alg. Am.-Bor. Exsicc., No. 162, but resembles *C. virescens* Farlow, 1881, p. 85, *Eudesme virescens* P. B.-A., No. 33, which is the same as *Mesogloia virescens* Carmichael in Wyatt, Alg. Danm., No. 49. Though some writers speak of *C. virescens* as having a solid axis, *C. Zosterae* as hollow, for instance Bornet, 1892, p. 236, the statement is true of the former only in the earlier stages. "A section of the frond of a well-developed *C. virescens* shows a circle of roundish cells around a central cavity"; Farlow, l. c. The description and figure of *C. Zosterae* Börgesen, agree with the Bermuda plant.

In New England and northern Europe there are two species of *Castagnea,* which are well distinguished by Farlow as *C. virescens* and *C. Zosterae;* the former resembles the Bermuda plant; the latter, quite distinct, is the *Myriocladia Zosterae* Crouan, Alg. Mar. Finistère, No. 49, and the *Castagnea Zosterae* of Le Jolis, 1863, p. 85, fide spec. authent.; but it may be open to question whether it is the *Mesogloia virescens* var. *zostericola* Harvey, 1846–1851, Pl. LXXXII, of which Harvey says "only differs in being of smaller size, with less compound ramification; there is no microscopic character to distinguish it." And in the Nereis Bor.-Am., part 1, 1852, p. 127, where he recognizes two species as distinct, he questions the identity of his *Mesogloia Zosterae* with the species of Lyngbye and Areschoug. His plate X. B, *M. virescens,* is drawn from a specimen from Sand Key, Florida, to which we will refer later; we do not think it is the *M. virescens* of New England and northern Europe. Plate X. A, *M. Zosterae,* is incorrect and misleading, as pointed out by Farlow. If it should prove that *Rivularia Zosterae* Mohr, 1810, p. 367, was identical with *Mesogloia virescens* Carmichael, *Castagnea Zosterae* would be the proper name for the spring plant of New England and northern Europe, and a new name would be needed for the smaller summer plant now known by that name. As to the identity of *C. virescens* of New England and northern Europe with the Bermuda plant, we are not now prepared to point out distinctive characters. But the southern plant is usually stouter, less branched, and with a firmer gelatine. For the purpose of comparison we have examined a large number of specimens of *Castagnea* (or *Mesogloia*) *virescens* of northern Europe and New England, including specimens from Mrs. Griffiths, Mrs. Wyatt, Greville, Harvey, Le Jolis etc.; with very few exceptions they bore unilocular sporangia; none had plurilocular. Of *Castagnea* (or *Myriocladia*) *Zosterae* we have examined a considerable number, including specimens from Le Jolis and Crouan, and the No. 162 of Farlow, Anderson

& Eaton; with one exception, sterile, all had plurilocular sporangia, none unilocular. Of the Bermuda plant we have examined many specimens of different ages and from different stations; with the exception of a very few, very young or very old individuals, sterile, all bear both uni- and plurilocular sporangia on the same individual. To add to the confusion, the plant from Florida, distributed as *C. mediterranea,* P. B.-A., No. 481, when compared with the Bermuda plant now seems to be distinct both from that and from *Cladosiphon mediterraneus* Kütz. The peripheral filaments seem to be not so much laterally attached to the external longitudinal filaments as continuations of them or their branches; the basal cell, up to 25 μ diam., followed by several similar colorless cells rapidly diminishing to about 12 μ diam.; above this begins the peripheral filament proper, with colored cells about 7–9 μ diam.; this is several times dichotomous, the cells, except the few lower ones, spherical, increasing in size up to 15 μ, sometimes to 20 μ diam., the filaments strongly incurved; unilocular sporangia, 70–80 × 55–60 μ in the lower forkings. The frond does not exceed 10 cm. in height, and has few branches. Harvey's figure of *Mesogloia virescens,* 1852, Pl. X. B, was drawn from a plant from Sand Key, Florida, and we have examined two specimens collected by Harvey at that place at that time; they agree with P. B.-A., No. 481, except that they have no fruit. In Harvey's plate fig. 4 represents quite well the upper part of a peripheral filament of this plant, but is quite different from a filament of *C. virescens.* We have found only one European specimen agreeing with P. B.-A., No. 481; this is "No. 572, Société dauphinoise, 1882, *Cladosiphon mediterraneus* Kütz. (Vidit Bornet, 1882) Portofino (Ligurie orientale) sur les feuilles de *Posidonia Caulini.* Dr. A. Piccone, Mai, 1876." This specimen was received by one of us from Dr. Piccone. Sauvageau, 1897, p. 46, discusses *Castagnea,* assuming correctly enough that if *Castagnea* is maintained, *Cladosiphon* Kützing should be divided between *Castagnea, Nemacystus* etc. But the name *Cladosiphon* clearly antedates *Castagnea,* and under the international rules should be retained for *C. mediterraneus* and its congeners. *Eudesme* J. G. Agardh seems to have no claim to distinctness from *Cladosiphon.* We refrain from making any new combinations, in the hope that Kuckuck's work on the Phaeophyceae may soon appear, and bring order out of the present chaos.

FAMILY STILOPHORACEAE.

STILOPHORA J. G. Agardh.

S. RHIZODES (Ehrh.) J. G. Agardh, var. ADRIATICA (Ag.) J. G. Agardh, 1848, p. 85; *Sporochnus adriaticus* Agardh, 1827, p. 646; 1828–35, Pl. XXX. Harrington Sound, April, Hervey, with plurilocular sporangia. More slender and delicate than the typical *S. rhizodes*, which is of a more northern range.

FAMILY SPOROCHNACEAE.

SPOROCHNUS Agardh.

S. BOLLEANUS Montagne in Kützing, 1859, p. 33, Pl. LXXXI, fig. II; P. B.-A., No. 2174. Dredged in 22 meters on coral rocks in June, Kemp, as *S. pedunculatus;* handsome plants with assimilative filaments well developed, Castle Island, Miss Wilkinson; a similar plant, Miss Peniston, no data; Gravelly Bay, old plants with mature fruit, washed ashore, Aug., Collins; dredged near Challenger Reef, in 60 meters, Aug., 1903, Bermuda Biological Station.

FAMILY TILOPTERIDACEAE.

HETEROSPORA Kuckuck.

H. VIDOVICHII (Meneg.) Kuckuck, 1895, p. 318, Pl. IV, figs. 1–20; *Haplospora Vidovichii* Bornet, 1891, p. 363, Pl. VIII, figs. 1–5; P. B.-A., No. 2026; *Ectocarpus Vidovichii* Meneghini in Kützing, 1845, p. 233; *E. crinitus* Hauck, 1885, p. 330, not of Carmichael. Forming rather dense tufts, up to 4 dm. long, on wall of inlet by the Frascati Hotel, March, Hervey, with monosporangia. The occurrence here of a representative of the family Tilopteridaceae is of much interest; barely half a dozen species are known, and all but this one inhabit the colder waters of the Atlantic. *H. Vidovichii* inhabits the Mediterranean, and this is its first recorded occurrence elsewhere.

FAMILY FUCACEAE.

ASCOPHYLLUM Stackhouse.

A. NODOSUM (L.) Le Jolis, 1863, p. 96; *Fucus nodosus* Linnaeus, 1763, p. 1628; Harvey, 1846–51, Pl. CLVIII. Wadsworth, in Farlow herb.; Inlet, Jan., May, Gravelly Bay, Feb., Shelly Bay, March, Hervey; Gravelly Bay, April, Shelly Bay, Bethel's Island, Dec., Collins. This species is not uncommonly found among the floating algae left by the tide but it has never been found attached, and as it is a conspicuous plant, it is not likely that it has been overlooked. It is common on the American coast from New Jersey to the arctic regions, but rarely reaches to low water mark, and does not grow in places exposed to the full force of the waves. There is no reason to suppose that it grows here in deep water, or on the outer reefs awash with the waves, the only class of localities not well explored. Prof. Sauvageau, to whom we are much indebted for information as to its habits in Europe, writes us "Jamais je n'ai vu l'*Ascophyllum* dans les stations franchement exposées au choc des vagues, mais toujours dans les stations plus ou moins abritées, par exemple dans les anses rocheuses, dans les petits ports, sur les rochers qui émergent parmi la vase. C'est une plante de mi-marée." As regards the general question of brown algae washed ashore in places on the Bay of Biscay, where they do not grow, he says, "En résumé, l'*Ascophyllum*, rejeté, arrive en très bon état, fructifié ou non, selon la saison, mais on ne peut dire s'il a flotté très longtemps, puisqu'il vit sur les rochers à une trentaine de kilometres de là. *L'Himanthalia* est dans le même cas. Mais le *Cystoseira concatenata* et le *Sargassum vulgare* viennent surement de très loin, et cependant leurs organes reproducteurs sont aptes à la fecondation. Les algues brunes, normalment fixées, se conservent très bien à l'état flottant, beaucoup mieux qu'on le croit generalment. Donc, à mon avis, il n'est nullement nécessaire que l'*Ascophyllum* croisse aux Bermudes pour que vous l'y trouvez rejeté; il peut y arriver en très bon état, et même capable de produire des fécondations et des germinations, bien qu'il provienne d'un pays lointain et qu'il ait flotté longtemps." It seems to us quite unlikely that the plants found at Bermuda could have come from the American coast across the Gulf Stream. The chances are certainly greater for its European origin, and there is good reason to suppose that it forms a portion, a relatively small portion, to be sure, of the living and floating brown algae of the North Atlantic, which have given a certain district of it the name of the "Sargasso Sea." Bouvier, 1907, p. 35, says "Ça et la, parmi les Sargasses, on rencontre quelques fragments de Fucus nodosus, arrachées certainement aux rivages des Canaries, de Madère ou des Açores." To be sure, Sauvageau, 1907, p. 1084, points out that the *Fucus* (*Ascophyllum*) has never been reported growing at the Canaries, Madeira or the Azores; but Bouvier's erroneous assumption does not invalidate his record of the occurrence of the plant as described. Börgesen, 1914a, p. 14, note, says "Professor Gran has most kindly communicated me that *Ascophyllum* was found in the northern part of the Sargasso Sea, and rather abundant." We think it may be concluded that *Ascophyllum*, the original derivation unknown, continues to live in a floating state among the *Sargassum* of the North Atlantic in active vegetation, and at least occasionally fruiting.

FUCUS Linnaeus.

F. VESICULOSUS Linnaeus, 1763, p. 1636. A single battered but unmistakable fragment was found washed ashore, Hervey.

TURBINARIA Lamouroux.

T. TRICOSTATA Barton, 1891, p. 218, Pl. LIV, fig. 3; P. B.-A., No. 1877. Gravelly Bay, Jan., Feb., March, April, Aug., Oct., Nov., Dec., Hervey; Hungry Bay, July, Collins. Except a few plants from near the entrance of Hungry Bay, the only locality we have observed is at Gravelly Bay, where it grows abundantly in pools at low water mark and sometimes higher up. *T. trialata* Kütz., the common species of the West Indies, we have not found, and though the two species have much in common, we have found no plants that would raise any doubt as to their distinctness. Quite young plants were found in August; in these neither alae nor costae had yet been formed. The mature plants, in December and January, are from 10 to 15 cm. high; the root is rather slender, much branched, 2–4 cm. long; as the plants grow close together, the roots are intermixed, but so loosely that individual plants can be separated without difficulty.

SARGASSUM Agardh.

The Sargassa abound everywhere in warmer water; there have been very many species described, and new ones are continually added to the list; undoubtedly there have been many cases where observers from distant regions have described the same species independently and in good faith; ultimately one of the names must give way to the other. On the other hand more conservative botanists have used the name of a well-known species for a form found at a station distant from the home of the species, and sooner or later the later named form will have to be segregated. Whether mistakes made by too radical or by too conservative treatment are more harmful, will probably remain an open question in botanical as in other matters. In our treatment of the Bermuda species, we find in some of them more or less noticeable differences from the species of the same name elsewhere, and we have given an account of the characters of each of the species we recognize, and have drawn these characters from Bermuda specimens, not from descriptions of others.

Key to the Species of Sargassum.

1. Always floating, without fruit or basal attachment.	2.
1. Attached, fruiting.	3.
2. Slender throughout, the leaves very narrow, with aculeate teeth.	1. S. natans.
2. Stouter; leaves lanceolate with triangular teeth.	2. S. fluitans.
3. Stem densely muriculate or with short proliferations.	4.
3. Stem not muriculate, or only slightly and occasionally so.	5.
4. Leaves ovate or broadly lanceolate.	4. S. lendigerum.
4. Leaves narrowly linear, simple or 1-several times forked.	3. S. linifolium.
5. Fructification long, slender, filiform, loosely branched.	6. S. Filipendula var. Montagnei.
5. Fructification not so slender or elongate.	6.
6. Receptacles with dentate wings.	S. S. platycarpum var. bermudense.
6. Receptacles wingless.	7.
7. Individual receptacles on slender pedicels.	3. S. linifolium.
7. Receptacles fertile throughout.	8.
8. Receptacles forming a dense glomerule.	7. S. Hystrix.
8. Receptacles repeatedly forked, branches separate.	5. S. vulgare.

1. S. NATANS (L.) J. Meyen, 1838, p. 185; Börgesen, 1914, p. 7; P. B.-A., No. 2180; *S. bacciferum* Agardh, 1821, p. 6; Harvey, 1852,

p. 54; *Fucus natans* Linnaeus, 1753, p. 1160; *Fucus bacciferus* Turner, 1808, p. 105, Pl. XLVII. Stem long, slender, smooth, with more or less distant similar branches; leaves long, slender, linear, with many sharp teeth, cryptostomata wanting or inconspicuous; vesicles numerous, on long slender pedicels, and usually with a filiform prolongation; fructification unknown; unattached, floating near the surface of the sea, forming loose floating patches, or strips in the line of the direction of the wind; in quiet water the tips of the leaves project above the water, like bristles; drifting ashore at all times, and in case of storms in immense quantities, and used as a fertilizer. It inhabits a large area in the North Atlantic, within a boundary formed by the Gulf Stream and its subsidiaries, reaching the coast of Europe, turning south and then west to its origin in the Gulf of Mexico. It has an active vegetative growth, the lower part of the stem decaying, increasing the number of individuals by fragmentation. It has never been found attached nor in fruit, and though in all probability originally derived from an attached form, it now appears to be so changed by its mode of life that it is unlikely that the attached species from which it was derived will ever be certainly determined.[10]

In several instances there have been reports of finding this species in fruit, but in each case when examined there are circumstances leading to the conclusion that the plant observed belonged to some other species.

2. S. FLUITANS Börgesen, 1914a, p. 222; P. B.-A., No. 2177; *S. Hystrix* var. *fluitans* Börgesen, 1914, p. 11, fig. 8. Stem rather stout, mostly smooth, occasionally with a few spines, much branched; leaves lanceolate to ovate-lanceolate, thickish, cryptostomata present but not conspicuous, teeth short and triangular; vesicles spherical, about 5 mm. diam., short-pedicelled, usually without prolongations; fructification unknown. Floating with *S. natans*, but less abundant; propagated by fragmentation only. It may be derived from *S. Hystrix* J. Ag., but if so the derivation is remote and the differentiation considerable. Both *S. natans* and *S. fluitans* are lighter in color than the attached species.

3. S. LINIFOLIUM (Turn.) Agardh, 1848, p. 18; P. B.-A., No. 2179; *Fucus linifolius* Turner, 1811, p. 64, Pl. CLXVIII. On rocks above and below Flatts bridge and at other points in Harrington Sound and in Hamilton Harbor, Hervey, Collins. From a common base but without any general trunk arise several axes with more or less frequent

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[10] For fuller discussion of floating Sargassum, see Collins, 1917.

branches, elongate, virgate, bearing leaves, fructification, and short branches; stems slender, terete, densely muriculate with short simple or forked papillae, which are occasionally more scattered on the older parts; leaves thickly set at the tips of the main branches and along short lateral branches, linear and attenuate to both ends, 1–2 mm. wide, up to 5 cm. long, simple or forked, margin irregularly dentate with small distant teeth, in young leaves larger and more frequent; midrib not specially conspicuous; cryptostomata rather large, a single series each side of the midrib, rather irregularly spaced; vesicles 3–6 mm. diam., smooth, or sometimes with cryptostomata, subspherical on a filiform pedicel of uniform diameter, or pyriform on a pedicel enlarged above; pedicel smooth, length one and one half to three times the diameter of the vesicle, usually unarmed, occasionally with a small mucro, rarely with a short filiform prolongation. Rachis of fructification usually short, sterile and filiform, or fertile and torulose, bearing several alternate, torulose, fertile branches, with subacute tip, one half to one cm. long; fructification mostly on the lower part of short branches of the second order with leaves about them on the branches.

The above description refers to the attached plant of quiet waters, but individuals more slender than the typical form can be found, in which the stem is almost entirely smooth and the rachis of fructification quite elongate. As with other species of *Sargassum*, individuals are to be found among the masses of *S. natans* floating after storms, and these show a certain resemblance to the latter, but their condition shows indications of their not persisting.

4. S. LENDIGERUM (L.) Agardh, 1820, p. 9; P. B.-A., No. 2178; *Fucus lendigerus* Linnaeus, 1763, p. 1628; Turner, 1808, p. 107, Pl. XLVIII. South shore, various points, Jan., Feb., Apr., Dec., Hervey; Little Agar's Island, Nov., Collins. Common on exposed rocks in shallow water all around the islands. A stout torulose trunk, 1–3 cm. high, divides into several main axes, often unbranched, occasionally rather freely branching; axes and branches terete, usually thickly set with short, simple or forked proliferations, rarely over 1 mm. long; leaves ovate or broadly lanceolate, margin irregularly undulate or slightly dentate; occasionally forked, usually much crisped, midrib distinct, cryptostomata small, scattered; vesicles spherical, smooth, usually about 3 mm. diam., occasionally 5 mm., on filiform pedicels usually shorter than the diameter of the vesicle, rarely with short tips. Fructification of filiform branching receptacles, the main rachis usually distinct, stouter than the radial branches, which may reach a length of 2 cm. in the looser forms, but usually do not reach a length of 1 cm.;

branching more or less dense, when dense often apparently dichotomous, tips acute; sometimes fertile throughout, sometimes rachis or even branches sterile. Fructification mostly on the upper part of the axes, often occupying these to the exclusion of leaves and vesicles, but also sometimes on short branches on the lower part of the axes. Specially a plant of exposed shores.

5. S. VULGARE Agardh var. FOLIOSISSIMUM (Lamour.) J. G. Agardh, 1889, p. 108; *Fucus foliosissimus* Lamouroux, 1813, p. 36, Pl. VII, fig. 1. Cooper's Island, April, Hervey. From a very short trunk arise several main axes, mostly smooth, sometimes slightly muriculate, bearing more or less numerous similar branches; leaves lanceolate to oblong, the margins finely and closely dentate; midrib distinct, cryptostomata abundant and without definite order on the younger leaves, often obsolete on the older and thicker leaves; vesicles spherical, 3–5 mm. diam., without prolongation, on a pedicel equal to the diameter or longer; receptacles axillary, branching, fertile throughout, verrucose, shorter than the leaves.

At Spanish Point, March, Hervey, was found a form probably belonging here, but without fruit; the leaves are narrower and nearly entire; it may be *S. vulgare*, typical; *S. vulgare* varies much in the size and form of the leaves.

6. S. FILIPENDULA Ag., var. **Montagnei** (Bailey) comb. nov.; *S. Montagnei* Bailey in Harvey, 1852, p. 58, Pl. I. A; *S. vulgare* var. *Montagnei* Farlow, 1881, p. 103; *S. Filipendula* forma *subedentata* J. G. Agardh, 1889, p. 120. Kemp; near Wistowe, floating, Aug., Collins. Stem long, slender, filiform, smooth except for a few minute, scattered papillae on the younger parts, loosely branched; leaves linear, usually 3–6 mm. wide, up to 15 cm. long, often one or more times forked, the divisions sometimes equal and symmetrical, oftener subpinnate and alternate; leaves tapering gradually or abruptly to the subacute tip; midrib distinct throughout leaves and their divisions; cryptostomata few, small, scattered, rarely showing a linear arrangement; margin even or slightly undulate or indistinctly dentate; vesicles spherical to subpyriform, 2–3 mm. diam., tipped generally with a mucro, often with a leaf; pedicel in length one and one half to three times the diameter of the vesicle, sometimes filiform, often compressed, or with midrib and margin. Rachis of fructification filiform, smooth, sterile, elongate, bearing rather distant lateral branches at first with sterile base, later fertile throughout, sometimes with a second series of similar branches, all branches at right angles, of uniform diameter, torulose; ultimate divisions up to 3 cm. long.

Generally characterized by the slenderness and delicacy of all the parts; typical *S. Filipendula,* stouter and shorter, with broader and more dentate leaves and more condensed fructification, has not been found here.

7. S. Hystrix J. G. Agardh, 1847, p. 7; 1889, p. 91, Pl. VI. Stem terete, smooth; leaves thickish, lanceolate or ovate-lanceolate, entire or obscurely dentate, 3–6 cm. long, 4–8 mm. wide, midrib rather indistinct, no cryptostomata; vesicles spherical, up to 7 mm. diam., pedicel short, sometimes imperceptible; fructification in dense glomerules of short, verrucose branches; receptacles, vesicles and leaves densely packed along the little branched axis. Harris Bay, Dec., attached, Hervey; washed ashore on Agar's and Bethel's Islands after a storm, Dec., Collins. Apparently recently torn from its attachment.

While our plant appears to agree in all other respects with *S. Hystrix,* the receptacles, though quite verrucose, show no spines or teeth. We should hardly have ventured to give it this name, but for what is said by Reinbold in Weber, 1913, as to sexual dimorphism in *Sargassum,* with presence or absence of spines on the receptacles according to sex. We suspect that another instance of dimorphism may be found in *S. platycarpum* Montagne and *S. vulgare* Agardh, at least the plant distributed under the latter name as P. B.-A., No. 178. We have seen a large number of plants from Florida, some with smooth, some with spiny receptacles, otherwise indistinguishable.

8. S. PLATYCARPUM Montagne var. BERMUDENSE Grunow, 1915, p. 389. We have not seen this, and include it only on the authority of Grunow.

Family DICTYOTACEAE.

Spatoglossum Kützing.

S. Schroederi (Mert.) J. G. Agardh, 1880, p. 113, in part; 1894, p. 38; P. B.-A., No. 2027; *S. Areschougii* Vickers. 1905, p. 58; 1908, part II, p. 38, Pl. XI; *Ulva Schroederi* Mertens in Martius, 1826, p. 21; 1827, Pl. II, fig. 3; *Taonia Schroederi* Farlow in Alg. Am.-Bor. Exsicc., No. 159. Gravelly Bay, Feb., March, Hervey; Gravelly Bay, April, Aug., Cooper's Island, Aug., Collins. Observed only at these two stations, and apparently not common. In the water it shows a brilliant iridescence. Tetraspores, much like those of *Dictyota,* were found on a few plants; there does not seem to have been any previous record of them. Tufts of hairs were common; the cells in a definite rectangular region divide, four cells from an original cortical cell, and each of these cells grows out into a hair; the hairs are contracted at base, lower cells about as long as their diameter, moniliform, with rich contents; upper cells 5–6 diam. long, cylindrical, nearly empty. It does not seem to us that the distinction made by J. G. Agardh between *S. Schroederi* and *S. Areschougii* can be maintained. Bermuda specimens show the forms of frond and characters of dentation characteristic of both species, as well as intermediate gradations.

ZONARIA Draparnaud.

1. Frond rounded, little divided; mostly dorsiventral and prostrate. 1. Z. variegata.
1. Frond erect, with many deep and narrow divisions. 2. Z. lobata.

1. Z. VARIEGATA (Lamour.) Mertens in Martius, 1826, p. 21; 1827, p. 6, Pl. II, fig. 2; Vickers, 1905, p. 58; 1908, Pl. VI. B; Börgesen, 1914, p. 197, figs. 151–152; *Dictyota variegata* Lamouroux, 1813, p. 57, Pl. V, figs. 7–9. Kemp, including some specimens marked *Z. lobata;* Wadsworth, No. 6; Moseley, from shallow water down to 31 fathoms; Hamilton Harbor, Agar's Cave, Jan., Walsingham, Feb., Farlow; Gravelly Bay, Jan., Harrington Sound, Feb., Harris Bay, Jan., Nov.; Inlet, Dec., Hervey; Ely's Harbor, Aug., Collins. Common nearly everywhere. It is sometimes found with one side of the lamina quite firmly attached; sometimes the frond is quite free, with little difference between the two sides; these differences do not seem to depend on the depth of water. Dickie, 1874, p. 311, notes that the plants dredged in 31 fathoms were mostly bluish green in color.

2. Z. LOBATA Agardh, 1824, p. 265; Harvey, 1852, p. 105, Pl. VII. C; Vickers, 1905, p. 58; 1908, Pl. VI; Börgesen, 1914, p. 199; P. B.-A., No. 1876. Kemp; Tucker, No. 5; South Beach, near Paget, Farlow; Wadsworth, No. 11; Inlet, Jan., Dec., Gravelly Bay, Feb., March, Dec., Hervey; Gravelly Bay, July, Aug., Ely's Harbor, Hungry Bay, July, Cooper's Island, Aug., Collins. Young plants are common in Dec.; by the last of Jan. good sized plants are common, and the plants continue in good condition till May; after that, only old, battered fronds are to be found. It is common in quiet water as well as on exposed shores. The best locality we observed was at Gravelly Bay, where it grew in great tufts in pools and on rocks at low water mark. The color varies from light to dark brown, the substance from

thin and membranaceous to coarse and leathery; the dark, zonate lines are distinct in the thin, light colored form, imperceptible on the old, coarse and dark fronds. It differs much in the extent of division of the fronds, from broad-cuneate and little parted, to fronds consisting of innumerable narrow divisions, sometimes broad below, narrow above, always more or less cuneate with apex truncate. Under water it shows a very brilliant iridescence of peacock blue and green.

PADINA Adanson.

1. Epidermis persistent as an indusium over the spores. 2.
1. No indusium; spore band in middle of each second zone between bands of hairs. 4. P. gymnospora.
    2. Frond dark and thickish, not much calcified; in middle part 2–3 cells thick; bands of spores alternating with bands of hairs. 3. P. variegata.
    2. Lighter colored and thinner; distinctly calcified. 3.
3. Band of spores above each second band of hairs; frond normally 2 cells thick. 1. P. sanctae-crucis.
3. One band of spores above and one below each second band of hairs; frond normally 3 cells thick. 2. P. Pavonia.

1. **P. sanctae-crucis** Börgesen, 1914, p. 201, figs. 153–154; P. B.-A., No. 2082. Harris Bay, Jan., Nov., Hervey; Shelly Bay, April, Jew's Bay, Ely's Harbor, Hungry Bay, July, Gravelly Bay, Aug., Collins. A rather thin, delicate species, growing mostly in shallow, quiet water. The color is usually a quite light yellowish brown on the upper side, the under side being usually covered with a continuous but quite thin calcareous coating, white or bluish in color. The dried plant is papyraceous and brittle. Only tetrasporic fruit has been found, which was on plants collected in July and August. The indusium consists of the epidermis, which is pushed up by the spores as they grow, and finally ruptured; being very thin and transparent it is not always easy to make out, but it often happens that when it is pushed away from the frond, it retains the markings outlining the layer of cells beneath; in such case a fine network corresponding to the cells can be seen with the microscope by careful focusing, on a level with the top of the spores. This form of indusium has been noted in *Zonaria variegata* by Sauvageau, 1905, p. 11 (of reprint.)

2. **P. Pavonia** (L.) Gaillon, 1828, p. 371; Harvey, 1846–51, Pl. XCI; P. B.-A., No. 2081; *Fucus pavonius* Linnaeus, 1763, p. 1630.

Gates Bay, March, Gibbet Island, April, Hervey. In the Bermuda material identified with this species the frond is smaller throughout and generally more delicate than in *P. variegata,* averaging much the size and consistency of *P. sanctae-crucis,* and with a similar calcareous coating. Tetrasporic fruit was well developed on the material from both stations noted above. Sterile plants resembling the two species just mentioned abound in warm shallow water, but can be distinguished only by sectioning and counting the layers of cells. In *P. Pavonia* the sexual plant, which we have not found here, is monoecious; in *P. variegata* it is dioecious, in both it is rare. While all American forms of *Padina* were formerly placed under *P. Pavonia,* this seems to be the first occurrence of the species on this side of the Atlantic. The material from Florida distributed as *P. Pavonia,* P. B.-A., No. 1442a, and that distributed as *P. Durvillaei,* P. B.-A., No. 580b, should be referred to *P. variegata;* 1442b to *P. gymnospora.* The plant distributed as *P. Durvillaei,* 580a, closely resembles *P. gymnospora,* but in the specimens now accessible the frond is uniformly two cells thick, which would bring it under *P. australis* Hauck; but Mme. Weber, 1913, p. 180, suggests that the latter may be only a form of *P. gymnospora.* The true *P. Durvillaei* Mont., appears to be found only in the Pacific.

3. P. VARIEGATA (Lamour.) Hauck, 1887, p. 42; P. B.-A., No. 2083; Börgesen, 1914, p. 205, figs. 157–161; *Dictyota variegata* Lamouroux, 1809, p. 331. Kemp, May, June, July, as *P. Pavonia;* Shelly Bay, Harris Bay, Jan., Gibbet Island, Jan., Nov., Dec., Hervey; Inlet, July, Aug., Collins. Very variable in form, from orbicular and undivided up to 15 cm. diam., to fronds split into innumerable strips, or with many rounded proliferations; in texture from thin and papery to thick and tough. It is however always darker than the two preceding species, and with less conspicuous calcification, and it is more than two cells in thickness, except at the growing edge, and may be six layers in the older parts. Tetrasporic fruit is rather common, oogonia infrequent; antheridia are known in this species, but we have not found them here.

4. P. GYMNOSPORA (Kütz.) Vickers, 1905, p. 58; 1908, Pl. VII; Börgesen, 1914, p. 202, figs. 155–156; *Zonaria gymnospora* Kützing, 1859, p. 29, Pl. LXXI, fig. 11. Farlow, 1881, without exact station. Observed once only, but in good condition and fruit. Characterized among our species by the absence of indusium, the frond with one layer of small cells and one layer of large in cross section, the larger cells sometimes dividing so as to give a section of three cells; the spore bands in the center of every second space between hair bands.

Dictyopteris Lamouroux.

1. Frond thick, wide, Fucus-like. 2. D. Justii.
1. Frond thin, delicate. 2.
    2. Diagonal veins from midrib to margin. 3. D. plagiogramma.
    2. No lateral veins. 1. D. delicatula.

1. D. delicatula Lamouroux, 1809, p. 332, Pl. VI, fig. 2 B; Vickers, 1905, p. 58; 1908, part 2, Pl. III; Börgesen, 1914, p. 216, fig. 166; P. B.-A., No. 1924. Castle Harbor, Jan., Farlow; Cave, Gravelly Bay, Oct., Harris Bay, Heron Bay, Dec., Hervey. Not uncommon, but mostly small plants, not over 10 cm. high.

2. D. Justii Lamouroux, 1809, p. 330, Pl. VI, fig. 2 A; Vickers, 1905, p. 58; 1908, part 2, Pl. V; P. B.-A., No. 1925. Rein, as *Halyseris polypodioides;* Mosely, dredged in 31 fathoms; Wadsworth, March, No. 9; St. David's Island, April, Kemp, as *Fucus ceranoides;* Faxon; Gravelly Bay, Jan., Feb., Oct., Dec., Hervey; Gravelly Bay, April, July, Aug., Tucker's Town, April, Outer Reef, Ely's Harbor, Hungry Bay, July, Cooper's Island, Aug., Collins. Occasionally found growing just below low water mark, but mostly floating, coming from deeper water. Old and battered plants came in abundantly in August; only young plants were found in February. It may grow to a length of 40 cm. Most reports of species of *Fucus* from Florida and the West Indies are based on large specimens of this species. Tetraspores were found in abundance on plants collected in August; they occur on both sides of the frond, the sori originally circular, about 1 mm. diam., or elongate, about 1 mm. wide. They increase in size, often become confluent, forming irregular patches, more than 1 cm. across. The sporangia are broadly pyriform, about 45 μ high, 25–35 μ diam. seen from above, and closely packed.

3. D. plagiogramma (Mont.) Vickers, 1905, p. 58; 1908, part 2, Pl. IV; *Haliseris plagiogramma* Montagne, 1837, p. 356. Kemp, May, as *Haliseris polypodioides;* this single specimen, large and in fine condition, is the only Bermuda record.

Dictyota Lamouroux.

1. Margin with small sharp teeth. 3. D. ciliata.
1. Margin even or uneven, without teeth. 2.
    2. Frond rather broad, with more or less distinct rachis, bearing alternate divisions; tips not tapering, either blunt or with two points. 8. D. dentata.

2. Frond dichotomously branched, with or without lateral proliferations. 3.
3. Frond usually rather broad, very regularly dichotomous, axils usually wide, tips rounded, proliferations on old plants only. 1. D. dichotoma.
3. Not with above combination. 4.
4. Frond very narrow, almost filiform throughout. 5.
4. Frond of varying width, not appearing filiform throughout. 6.
5. Regularly dichotomous, few or no proliferations except in very old plants. 2. D. linearis.
5. Dichotomous in younger parts, elsewhere with many proliferations, often much entangled. 6. D. divaricata.
6. Fronds narrow, dichotomous, few or no proliferations. 7.
6. Fronds broad or narrow, divisions of dichotomies often unequal, sometimes appearing subpinnate, proliferations frequent. 5. D. Bartayresii.
7. Dichotomies distant, regular, divisions equal. 3. D. indica.
7. Dichotomies close, some divisions long, some short, patent, acute. 4. D. cervicornis.

1. D. DICHOTOMA (Huds.) Lamouroux, 1809, p. 331; Harvey, 1846–51, Pl. CIII; P. B.-A., No. 2175; *Ulva dichotoma* Hudson, 1798, p. 476. Rein; Hamilton, Kemp; up to 31 fathom depth, Moseley; Tucker, No. 11; Cave near Ducking Stool, Farlow; Faxon; Buildings Bay, Inlet, Dec., Hervey. This species, the common one of Europe and the most widely distributed of the genus, seems to be rather uncommon in Bermuda; we have found it of only moderate size, not at all like the large plants from North Carolina distributed as P. B.-A., No. CXX. Antheridia have once been observed, but no other form of fruit. There is little indication of rhizoidal filaments in the Bermuda plants.

2. D. LINEARIS (Ag.) Greville, 1830, p. XLIII; Kützing, 1859, p. 9, Pl. XXI, fig. II; P. B.-A., No. 2031; *Zonaria linearis* Agardh, 1820, p. 134. Jew's Bay, July, Collins. In loose floating masses, antheridia fairly frequent, no other fruit observed. The frond is very narrow, seldom over 1 mm.; the forkings are rather distant, axils narrow. The lower part of the frond was old and dry, but showed no proliferations; no rhizoidal filaments were seen.

3. D. INDICA Sonder in Kützing, 1859, p. 8, Pl. XVII, fig. 1; Vickers, 1905, p. 59; 1908, part 2, Pl. XVIII; P. B.-A., No. 2030. Kemp, as *D. fasciola*, in part; Ely's Harbor, Aug., Collins. Our plants agree with the narrower form distributed by Miss Vickers under No. 78; the width of the frond from 1–2 mm. remaining practically the same throughout in each individual. The divisions are quite

regularly dichotomous throughout, the axils rather wide and rounded, the divisions immediately incurving and often becoming parallel, the apices rounded. Antheridia of the usual form were found on these plants; also, on the same plants, scattered or in twos, tetrasporangia; none of these were found showing the regular division into fours, but in many the contents had divided into many small squarish cells, the sporangium enlarging to two or three times its former dimensions, and developing a point of growth at the tip. This closely parallels the development in *D. dichotoma,* described and figured by Reinke, 1878, p. 8, Pl. I, figs. 31–35. The occurrence on the same frond with antheridia is, however, noteworthy. We hardly see how *D. volubilis* Vickers, Algues de la Barbade, No. 78a, can be distinguished from the present species, apart from the spiral twisting of the frond. A plant in the Kemp herbarium, marked *D. fasciola,* is intermediate between *D. indica* and *D. volubilis* of the Algues de la Barbade.

4. D. CERVICORNIS Kützing, 1859, p. 11, Pl. XXIV, fig. II; *D. fasciola* Harvey, 1852, p. 108, Pl. VIII. B., not of Lamouroux. Rein, as *D. fasciola.* The true *D. fasciola* has slender fronds, regularly but not very closely dichotomous, the divisions all developing equally and ending at nearly the same level. In *D. cervicornis* one division is frequently short, acute and erect, giving quite a different habit, which is well characterized by the specific name.

5. D. BARTAYRESII [11] Lamouroux, 1809, p. 331; *D. Bartayresiana,* Harvey, 1852, p. 110, Pl. VIII. C.; P. B.-A., No. 1874. Kemp, as *D. fasciola,* in part; in shallow water, Moseley; St. David's Island, from half tide down, April, Shelly Bay, May, Gravelly Bay, Hungry Bay, July, Cooper's Island, Aug., Collins; Gibbet Island, Jan., Oct., Dec., Hervey. This seems to be the species of *Dictyota* occurring most frequently in Bermuda. It is quite variable, and narrow forms certainly show similarity to *D. divaricata.* On comparing the accounts given of the species by different authors, and the specimens from different localities distributed under this name, one is led to suspect that more than one species is really in question. As originally described, stress was laid on the acute apices, but later authors include forms with distinctly blunt apices. Both forms occur among the Bermuda material we have studied. It is probable that all species of the genus

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[11] This species is generally known as *D. Bartayresiana,* but in the original publication by Lamouroux the specific name is *Bartayresii.* Few authors refer to this rare and neglected paper, almost all starting from a later publication of the same year, 1809a, p. 43, in which the author, without stating any reason, substitutes the name *Bartayresiana.*

are subject to much variation with age and environment, and much study of living plants is needed before we can get a clear idea of specific lines. What we consider as the normal form of the species in Bermuda closely resembles No. 72 of Miss Vickers Algues de la Barbade; in this some apices are acute, some rounded, on the same individual. The branching seems intermediate between *D. dichotoma* and *D. dentata,* with a suggestion of lateral branching not found in the former, but not the distinctive character as in the latter. Antheridia were common in material collected at all seasons; tetraspores occurred occasionally on the same individual with antheridia, in July and August. No rhizoidal filaments were seen. Mme. Weber, 1913, p. 182, states that the type of *D. Bartayresii* cannot be found; she speaks of Harvey's figure as excellent, and we have taken it for our standard.

6. D. DIVARICATA Lamouroux, 1809, p. 331, not of Kützing, 1859, p. 10, Pl. XXIII, fig. 1; *D. acutiloba* Kützing, 1859, p. 13, Pl. XXIX, fig. 1, not of J. Ag. Inlet, Gravelly Bay, Dec., Hervey. Fronds as narrow as in *D. linearis,* but the dichotomous habit, distinct in young growing branches, is quite obscured in the older parts by the abundant, mostly short, proliferous branches. By these the fronds are often so densely matted that it is not easy to disentangle any individual plant. Antheridia are abundant in this material, but no other form of fruit was observed. The fronds seem to attach themselves by interlaced proliferous branches, with a few short, monosiphonous rhizoidal filaments close to the tip.

7. D. CILIATA J. G. Agardh,[12] 1841, p. 5; Harvey, 1852, p. 110, Pl. VIII. A.; *D. crenulata* P. B.-A., No. 1875, an J. Ag. ?. Rein; Kemp, May, June; South Shore near Paget, Feb., Castle Harbor, Feb., Farlow; Gravelly Bay, Jan., Feb., Harris Bay, Dec., Hervey; Causeway, April, Shelly Bay, May, Hungry Bay, July, Collins. There is considerable variation in the material which we now include under *D. ciliata,* but after a re-examination of the form that we distributed as *D. crenulata,* we do not feel justified in keeping it distinct. It seems to us also that *D. crenulata* from Barbados, Vickers, No. 75,

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[12] The first use of the combination *Dictyota ciliata* is by Lamouroux, 1809, p. 331, where a synonym is given, *Fucus pseudociliatus* Lamouroux, 1805, p. 41; a description is given of the latter and figure, Pl. XXX, fig. 2; the locality is the Mediterranean. It is now generally acknowledged to be *Taonia atomaria* (Good. & Woodw.) J. Ag. Being a name proposed for a plant recognized by Lamouroux as already named, *Dictyota ciliata* Lamouroux never had any standing, and cannot interfere with the subsequent *D. ciliata* J. Ag.

of which we have examined several specimens, belongs under *D. ciliata*. Agardh, 1848, p. 94, says of *D. crenulata* "margine tenui dentibus brevissimis late triangularibus initio fere serrato, demum dentato aut crenato." Harvey, 1852, says "The margin is undulated, and closely eroso-denticulate, or jagged with unequal, deltoid or subulate, tooth-like processes." In the Bermuda plants the margin is quite even, and the teeth are of uniform size and never very closely set. We have, however, seen a specimen of *D. crenulata* from the Suhr herbarium "West Indien," that fully agrees with Agardh's and Harvey's descriptions. In the Bermuda material of this species confervoid rhizoidal filaments arise from the lower part of the main axis of the frond, often forming a dense, continuous mass for several cm.; proliferations are few and insignificant. Antheridia and oogonia were found on specimens collected in February, tetrasporangia on specimens collected in July.

8. D. DENTATA Lamouroux, 1809, p. 331; Kützing, 1859, p. 15, Pl. XXXV, fig. I; *D. Mertensii* (Mart.) Kützing, 1859, p. 15, Pl. XXXVI, fig. I; *Ulva Mertensii* Martius, 1826, p. 21; 1827, Pl. I; P. B.-A., No. 1926; *D. Brongniartii* J. G. Agardh, 1841, p. 5; Kützing, 1859, p. 15, Pl. XXXV, fig. II; *D. subdentata* Kützing, 1859, p. 14, Pl. XXXIII, fig. II. Kemp, as *D. crenulata*, in part; Gravelly Bay, Jan., Hervey, Aug., Collins; Hungry Bay, July, Collins. J. G. Agardh, 1880, p. 98, gives *D. Mertensii* as a synonym of *D. Brongniartii*, mentioning *D. subdentata* without expressing an opinion as to whether it should be referred to *D. dentata* or *D. Brongniartii;* later, 1894, p. 70, he recognizes *D. dentata*, *D. Mertensii* and *D. Brongniartii* as distinct species. Hauck, 1888, p. 466, unites all four under the oldest name, *D. dentata*, as it seems to us rightly. The distinctive characters are found in the greater or less distinctness of the axis and branches, and in the character of the terminal segments. In the abundant material we found in Bermuda, there were individuals with the primary axis narrower and firmer than the lateral segments, and others, apparently mostly younger individuals, in which all was uniformly membranaceous. Typical *D. dentata* has segments ending in acute, spinous tips; typical *D. Mertensii* has segments short-cuneate, with truncate or emarginate tips. It is not uncommon to find both these types on the same individual. In comparing the vegetative structure of *D. dentata* with that of *D. dichotoma*, as described by Reinke, 1878, several points are to be noted. The main axis is thick, and somewhat flattened, but can hardly be described as a "rundtrieb." In old plants, there grow from this, for a distance of

three or four cm. from the base, descending, terete, branching filaments, of an average diam. of one half mm., forming a loose felt. A cross section shows a densely cellular structure, the cells much smaller than in the median layer of the frond, the superficial cells much like those of the frond. From the superficial cells issue, not continuously but in groups, monosiphonous filaments, 20–25 μ diam., the cells 2–4 diam. long, nodes somewhat constricted; these filaments are mostly simple, occasionally with short branches; when a filament reaches the substratum the terminal cell forms a coralloid expansion as an organ of attachment. Other species of *Dictyota, D. ciliata* for instance, are attached by rhizoidal filaments of a similar character, but arising directly from the frond; *D. dentata* is the only Bermuda species in which they arise from descending cellular branches. In older plants prolifications are common from the surface of the frond, sometimes papillose to clavate, sometimes flattened with rounded outline. None were observed over 1 mm. in length; the papillose-clavate form seemed to be of a similar character to the descending filaments developed near the base. Antheridia were common in material collected in Jan., July and Aug.; no other fruit was observed.

DILOPHUS J. G. Agardh.

D. GUINEENSIS (Kütz.) J. G. Agardh, 1880, p. 108; Vickers, 1905, p. 59; 1908, part 2, p. 37, Pl. IX; Börgesen, 1914, p. 214, figs. 164–165; P. B.-A., No. 2080; *Spatoglossum guineense* Kützing, 1843, p. 339; 1859, Pl. XLVI, fig. I. South Shore near Paget, Farlow; Gravelly Bay, March, Hervey.

CLASS **RHODOPHYCEAE.**

FAMILY BANGIACEAE.

BANGIA Lyngbye.

B. FUSCOPURPUREA (Dillw.) Lyngbye, 1819, p. 83, Pl. XXIV. C; P. B.-A., No. 2084; *Conferva fuscopurpurea* Dillwyn, 1809, p. 54, Pl. XCII. On exposed rock, North Shore near Shelly Bay, April, Fairyland, Dec., Collins; in tufts on wall by Palmetto Vale, Harrington Sound, March, Hervey. In the North Shore and Fairyland stations there were scattered filaments only, imperceptible except on microscopic examination. At the Sound station the tufts were several cm. long. In all cases it was a slender form, mostly monosiphonous, rarely over four cells to a segment.

PORPHYRA Agardh.

P. ATROPURPUREA (Olivi) De Toni, 1897, p. 17; P. B.-A., No. 2085; *P. leucosticta* P. B.-A., No. 1927; *Ulva atropurpurea* Olivi, 1791, p. 153, Pl. I–III. Kemp, May, as *P. laciniata*; "Spitall Lake Ferry" May, Kemp, unnamed specimen in herb.; on mangroves below Flatts Bridge, April, May, Collins; Ely's Harbor, May, Hervey. At Flatts Bridge the *Porphyra* began to be visible about April 20, 1912, growing on mangroves in company with *Monostroma latissimum;* both minute when first observed, but growing rapidly up to May 3, when we left Bermuda. When next at this place, from July to Sept., 1913, the *Porphyra* was not to be found. The Ely's Harbor plant is of moderate size, up to 6 cm. long; the specimens in the Kemp herbarium reach 10 cm. in length. *P. vulgaris* of Moseley is undoubtedly this species.

ERYTHROTRICHIA Areschoug.

E. CARNEA (Dillw.) J. G. Agardh, 1882, p. 15, Pl. I, figs. 8–10; P. B.-A., No. 2032; *E. ceramicola* Farlow, 1881, p. 113; *Conferva carnea* Dillwyn, 1809, p. 54, Pl. LXXXIV. Common on various algae, Jan., Feb., Hervey; April, May, July, Aug., Nov., Dec., Collins; on submerged tamarisk branches, Harrington Sound, May, Collins.

ERYTHROCLADIA Rosenvinge.

E. SUBINTEGRA Rosenvinge, 1909, p. 73, figs. 13–14; Börgesen, 1915, p. 7, figs. 3–4; P. B.-A., No. 2086. On *Bryopsis pennata*, Tucker's Town, April; on *Caulerpa crassifolia*, Hungry Bay, May, Collins; on *Cladophora catenifera*, Gravelly Bay, Feb., Hervey. Probably common, but perceptible only on microscopic examination when it appears in the form of minute orbicular disks, of closely set radiating filaments, dichotomously branched, united laterally except at the edge, closely adherent to the host. At Gibbet Island it grew in company with *Pringsheimia scutata*, the fronds of which have much the same structure; their bright green color contrasts strongly with the red of the *Erythrocladia*.

GONIOTRICHUM Kützing.

1. Filaments one or at most two cells wide. 1. G. elegans.
2. Main filaments many cells wide. 2. G. Humphreyi.

1. G. ELEGANS (Chauv.) Le Jolis, 1863, p. 103; Rosenvinge, 1909, p. 75, fig. 15; Börgesen, 1915, p. 4, fig. 2. *Bangia elegans* Chauvin, 1842, p. 33. On many species of algae, especially on *Codium* and its epiphytes, very frequently met with as isolated individuals, rarely in large quantity. The filaments are often simple; when branched, the branching approaches lateral rather then dichotomous; the cells are 10–15 μ diam., spherical or slightly compressed or elongate; they are smallest at the base of the filament, largest near the apex, while the filament is largest at the base, up to 25 μ, tapering slightly towards the apex. Lateral division of cells by an oblique wall is not uncommon. It is quite distinct from the duplication by displacement described by Rosenvinge, 1909, p. 75, and seems to be a normal process.

2. G. HUMPHREYI Collins, 1901, p. 251; P. B.-A., No. 421; *Bangiopsis subsimplex* Börgesen, 1915, p. 10, figs. 5 and 6, not *Compsopogon subsimplex* Mont. Among other algae, *Ectocarpus Mitchellae*, *Calothrix fusco-violacea*, *Enteromorpha* species, etc., forming a dense growth on the bottom of a rock pool near Gravelly Bay, Jan., Hervey. The fronds are more freely branched than in the material from Jamaica, but the main stems are not as stout; otherwise they are identical.

FAMILY HELMINTHOCLADIACEAE.

ACROCHAETIUM Nägeli.

A conservative course has been followed by us in regard to the plants belonging to this genus. No such richness of new forms has been found here as by Börgesen in the Danish West Indies, but we cannot claim to have made as thorough a study as he has, and it is very unlikely that all the Bermuda forms have been discovered and listed. We include under *Acrochaetium* the marine species formerly passing under *Chantransia*, many of which have recently been juggled back and forth, only too often.

1.	Original spore remaining manifest at base of filament.	2.
1.	Original spore not distinguishable.	5.
2.	Basal cell with descending endophytic and erect free filaments.	3.
2.	No descending endophytic filaments.	4.
3.	Cells 8–10 μ diam., 4–5 diam. long.	3. A. corymbiferum.
3.	Cells 12–14 μ diam., 2–3 diam. long.	4. A. barbadense.
4.	Cells short, subspherical.	2. A. crassipes.
4.	Cells long, cylindrical.	1. A. Dufourii.
5.	Frond arising from a disk.	8. A. Thuretii.
5.	Frond not arising from a disk.	6.
6.	Horizontal filaments on surface of host.	7.
6.	Horizontal filaments endophytic only.	9. A. Hypnae.
7.	Horizontal filaments producing endophytic branches.	7. A. Nemalionis.
7.	Horizontal filaments without endophytic branches.	8.
8.	Erect filaments 6–12 μ diam.	6. A. Sagraeanum.
8.	Erect filaments 4–5 μ diam.	5. A. leptonema.

1. A. DUFOURII Collins, P. B.-A., No. 1594; *Chantransia Dufourii* Collins, 1911, p. 187; P. B.-A., No. 2087. On *Dictyota ciliata*, Hungry Bay, Dec., Hervey. Forming a dense fringe on the edge of the host. The basal cell (original spore) remains distinct, attached to the host by a circular disk, of diameter larger than that of the cell. This development is of the same character as that in *Chantransia collopoda* Rosenvinge, 1909, p. 81, but on a smaller scale; it is found also in another Bermuda species, *A. crassipes*.

2. A. CRASSIPES Börgesen, 1915, p. 20, fig. 11; *Chantransia crassipes* Börgesen, 1909, p. 1, fig. 1; P. B.-A., No. 2033. On *Ceramium clavulatum* and *Polysiphonia ferulacea*, St. David's Island, Feb., and on *Callithamnion Hookeri*, Gravelly Bay, April, Hervey.

3. **A. corymbiferum** (Thuret) comb. nov.; *Chantransia corymbifera* Thuret in Le Jolis, 1863, p. 107; Bornet & Thuret, 1876, Pl. V, fig. 3; P. B.-A., No. 1880. On *Dudresnaya crassa*, Salt Kettle, Feb., Spanish Point, March, Buildings Bay, April, Hervey; Shelly Bay, May, Collins. In Europe and California this species occurs on *Helminthocladia calvadosii;* although the latter is common in Bermuda, the *Acrochaetium* has not been observed on it, but seems to occur generally on the *Dudresnaya.* Its filaments have some resemblance to those of the host, and the resemblance might puzzle one unfamiliar with both. But usually antheridia or cystocarps can be found.

4. A. BARBADENSE (Vickers) Börgesen, 1915, p. 45; *Chantransia barbadensis,* Vickers, 1905, p. 60. On *Liagora elongata,* Buildings Bay, March, Hervey. This plant resembles *A. corymbiferum,* but is kept distinct by Bornet, 1904, p. XX, as well as by Miss Vickers, the distinctive characters being the stouter and shorter cells, and the less developed basal portion. We have compared our plant with an authentic specimen from Miss Vickers, also on *Liagora elongata,* and find them to agree, except that while in the Bermuda plant most of the filaments are composed of cells agreeing in dimensions with Miss Vickers plant and description, in others the dimensions approach those of *A. corymbiferum.* It is possible that future observations may show that the difference is not specific.

5. A. LEPTONEMA (Rosenv.) Börgesen, 1915, p. 31; *Chantransia leptonema* Rosenvinge, 1909, p. 118, figs. 47–48. On *Dictyopteris Justii,* Gravelly Bay, Aug., Collins. Our smallest species of the genus.

6. A. SAGRAEANUM Bornet, 1904, p. XXI; P. B.-A., No. 2181; *Cladophora Sagraeana* Montagne, 1838, p. 459. On *Zonaria lobata,* Gravelly Bay, Aug., Collins; On *Dictyopteris Justii,* Buildings Bay, July, Hervey. The Buildings Bay plant almost entirely covers the *Dictyopteris* with a dense coating, the individual plants up to 5 mm. high, main filaments about 12 μ diam., branches seldom under 7 μ. These dimensions are greater than those given by Bornet in his description, but as all other characters agree, it must be considered a luxuriant form of this species. Monospores, 18–22 × 8–10 μ were observed, on unicellular pedicels in a series on the inner side of a branch near the base. On other individuals were observed tetraspores, not before known for the species. They were arranged similarly to the monospores, but were larger and relatively broader, 28–34 × 17–27 μ. The division is in the form indicated by Rosenvinge, 1909, p. 85, as characteristic of the genus, cruciate with the first division horizontal;

sometimes the division proceeds no farther, but usually a vertical division occurs in one of the halves, often in both, but in the latter case the divisions of the two are seldom in the same plane.

7. A. NEMALIONIS (De Not.) Börgesen, 1915, p. 55; *Chantransia Nemalionis* Rosenvinge, 1909, p. 126, figs. 53–54; *Callithamnion Nemalionis* De Notaris in Erb. Critt. Ital., No. 952. Harrington Sound, April, Collins, growing on Tamarisk branches which had bent down until submerged. As in *A. Sagraeanum* the erect filaments arise from a plexus of irregular horizontal filaments, but in *A. Nemalionis* the latter emit descending filaments which penetrate the host. In the Bermuda plant these are less developed than in the European plant growing on *Nemalion*, probably on account of the more resisting character of the substratum of Tamarisk, as compared with *Nemalion*.

8. **A. Thuretii** (Bornet) comb. nov.; *Chantransia Thuretii* Kylin, 1907, p. 119, fig. 28; *C. efflorescens* forma *Thuretii* Bornet, 1904, p. XVI. On *Codium decorticatum*, Cooper's Island, Aug., Collins. With monospores.

9. A. HYPNEAE Börgesen, 1915, p. 51, fig. 54; *Chantransia Hypneae* Börgesen, 1909, p. 2, fig. 2. On *Ceramium clavulatum*, in company with *A. crassipes*, St. David's Island, Feb., Hervey. With monospores.

TRICHOGLOEA Kützing.

T. HERVEYI Setchell ms.; P. B.-A., No. 2034. In tide pools, Gravelly Bay, March, April, Hervey; from low water mark to two meters depth, near Cooper's Island, April, May, Collins. Extremely gelatinous, not calcified. Appearing in March, but not found after midsummer.

HELMINTHOCLADIA J. G. Agardh.

H. CALVADOSII (Lamour.) Setchell in P. B.-A., No. 2035; *Dumontia calvadosii* Lamouroux in Duby, 1830, p. 941; *Nemalion purpureum* Harvey, 1846–51, Pl. CLXI; *Helminthocladia purpurea* J. G. Agardh, 1851, p. 414. Bailey's Bay, Feb., Castle Harbor, March, Wadsworth; Dingle Bay, March, North Shore, April, Old Ferry Road, April, Hervey; Tucker's Town, St. David's Island, Long Bird Island, April, Collins. Specimens in Kemp herbarium, marked *Helminthora divaricata* and *Helminthocladia divaricata* both belong here. On stones from half tide down, not uncommon in quiet water; antheridia and cystocarps in April. Prof. Setchell has called our attention to Lamouroux's name which considerably antedates the Harveyan name in general use.

LIAGORA Lamouroux.

1. Not calcified. 4. L. pectinata.
1. Calcified. 2.
  2. Very soft and gelatinous. 3. L. pulverulenta.
  2. Firmer. 3.
3. Calcareous coating continuous and smooth. 1. L. valida.
3. Calcareous coating loose, penetrated by assimilative filaments. 2. L. elongata.

1. L. VALIDA Harvey, 1853, p. 138, Pl. XXXI. A; Börgesen, 1915, p. 70, figs. 71–75; P. B.-A., No. 1929. Rein; Kemp; St. David's Island, Feb., April, Buildings Bay, April, Hervey; Cooper's Island, April, Aug., Collins. The most common of the Bermuda species of *Liagora*, and generally easily recognized by the continuous calcareous coating and firm, little gelatinous consistency. It occurs in its best condition just below low water mark, but may extend up nearly to high water mark. In many places it forms a continuous zone between tide marks, the individual plants short and stunted, mostly chalky white. When growing in more favorable conditions a pinkish shade shows through the coating more or less.

2. L. ELONGATA Zanardini, 1851, p. 35; 1858, p. 274, Pl. VI, fig. 1; Börgesen, 1915, p. 67, figs. 67–70; P. B.-A., No. 2088; *L. corymbosa* J. G. Agardh, 1896, p. 104. Kemp, July, unnamed specimen in herb.; Miss Wilkinson; Gates Bay, Buildings Bay, March, St. David's Island, May, Hervey; Cooper's Island, Aug., Collins. Cystocarps in March. Not as variable as other species of the genus, and usually recognized easily by the light purple-brown color, the light and loose calcification, and the long, rather distantly dichotomous fronds, of nearly uniform diameter. *L. corymbosa*, according to J. G. Agardh, 1896, p. 104, "Hab. ad littora Floridae et insulas Bermudas." Specimens agreeing fairly well with Agardh's description were collected at Castle Harbor by Wadsworth, March, 1890; at Tobacco Bay, March 11, 1914, Hervey; but it is impossible to separate them from *L. elongata*. As to characters derived from internal structure used by Agardh in his treatment of the genus, l. c., we have not been able to apply them, as we find them inconstant. He divides *Liagora* into two subgenera, *Euliagora* and *Goralia*, the former with an inner layer

of longitudinal filaments, subdistant, large and small intermixed, the outer usually small, the fascicles of the cortical layer free from each other except as united by the general gelatinous coating. In *Goralia* the larger filaments of the inner layer are densely packed, the smaller being on the surface only, the fascicles of the cortical layer adherent and confluent. *L. pulverulenta* is placed in *Euliagora, L. valida* in *Goralia;* but in both species as they occur in Bermuda we have found large central filaments branching and producing smaller filaments, with no definite position in the central strand; generally the cortical fascicles are borne on the smaller filaments of the central strand, but not infrequently on the larger ones. The density of the cortical fascicles and their mutual adhesion or freedom seem to depend largely on age or activity of growth; they often vary much in the same individual.

3. L. PULVERULENTA Agardh, 1822, p. 396; Börgesen, 1915, p. 80, figs. 87–92; P. B.-A., No. 1928. Miss Peniston; Castle Harbor, Harrington Sound, Cooper's Island, March, Wadsworth; St. David's Island, Feb., May, Tobacco Bay, March, Hervey; Cooper's Island, Shelly Bay, April, Collins. Very soft and gelatinous, collapsing into a shapeless jelly when taken from the water, but not difficult to arrange in natural form on paper if dried without pressure or with very slight pressure.

L. pectinata sp. nov. Fronde submolli, ecalcarea, rubro-purpurea, ad 20 cm. alta; ramis primariis inferne nudis vel ramulis paucis brevibus munitis, superne ramos gerentibus frequentes breves, alternantes vel secundatos, ramulos similes gerentes; ramis et ramulis omnibus, primariis exceptis, plus minusve sinuosis et curvatis, ultimis patentibus, in- vel recurvatis, saepe pectinato-secundatis; apicibus abrupte acutis. Strato axili, circa 150 μ diam., filamentis dense compactis; cellulis circa 20 μ diam., 4–8 diam. longis; fasciculis filamentorum assimilatorium 600–800 μ longis, densis, aequilongis, superficiem aequalem continuam frondis formantibus; filamentis repetite dichotomis, cellulis inferioribus 5–7 μ diam., 5–8 diam. longis, subcyclindricis; superioribus brevioribus, crassioribus, ovoideis; terminalibus 8–10 μ diam., 2–3 diam. longis, interdum pilos breves, circa 4 μ diam., ferentibus. Fructificatione ignota.

Frond rather soft, without incrustation, dull red-purple, up to 20 cm. high; main branches naked below or with a few short ramuli, above with numerous alternate or secund branches, bearing similar ramuli, all but the main branches more or less sinuous and curved, the lesser divisions patent, in- or recurved, often pectinately secund; all tapering suddenly to an acute point. Central strand about 150 μ diam., of closely packed filaments, cells about 20 μ diam., 4–8 diam. long; fascicles of assimilative filaments 600–800 μ long, dense, even-topped, making a continuous smooth surface to the frond; filaments many times dichotomous, lower cells 5–7 μ diam., 5–8 diam. long, subcylindrical; upper cells shorter, stouter, more ovoid; end cells 8–10 μ diam., 2–3 diam. long, occasionally with a short hair, about 4 μ diam. Fructification unknown. Cooper's Island, April, Hervey.

The peripheral filaments do not arise directly from the cells of the central strand; at the summit of one of these cells a short conical or ovoid cell is formed, from which radiate the basal filaments of several peripheral fascicles; these filaments are usually straight and unbranched for 200–400 μ, then dichotomous. The substance is softer than in *L. valida*, not as soft as in *L. pulverulenta*. The reference to the genus *Liagora* is from the structural characters; we have found no fruit. As is well known, the amount of calcification varies much in the different species, but there is only one species recorded practically free from lime, *L. dubia* (Bory) Bornet in De Toni, 1905, p. 1628; *Cladostephus dubius* Bory, 1832, p. 331, Pl. XXXVIIbis, fig. 6. Little is known of this species beyond Bory's plate and description, but it seems to be quite distinct from the present species.

FAMILY CHAETANGIACEAE.

SCINAIA Bivona.

S. COMPLANATA (Collins) Cotton, 1907, p. 260; Setchell, 1914, p. 100, Pl. XI, figs. 19–22; *S. furcellata* var. *complanata* Collins, P. B.-A., No. 836; 1906, p. 110. Farlow. A single specimen in the Farlow herbarium is the only representative of the species and genus that we have seen from Bermuda; as the segregation of the forms till recently included under *S. furcellata* has only just been made, it is impossible to locate the *S. furcellata* recorded by Moseley, "a single specimen dredged."

GALAXAURA Lamouroux.

Representatives of this genus are common all around the islands, but the distinguishing of species is very difficult. We note below five species in regard to which we feel some confidence, but we have many collections that cannot be placed under any of them, and to which we do not venture to give names. Kjellman, 1900, gives full descriptions of many species founded by him on material in Scandinavian herbaria, but without descriptions of older species, and with little indication of the distinguishing characteristics between the latter and his new species. Howe, 1917, shows that in one case what Kjellman considers as two sections of the genus are really sexual and asexual forms of the same species. Beside the five species listed below, we can only say that we have also forms resembling *G. fasciculata* Kjellm., *G. ramulosa* Kjellm., and *G. fruticulosa* Kjellm. Moseley reports *G. rugosa* and *G. lapidescens*, from both of which species, as formerly understood, Kjellman segregated new species. Rein reports *G. fastigiata*, but we have not been able to see a specimen.

G. FLAGELLIFORMIS Kjellman, 1900, p. 47, Pl. III, figs. 2–11; Pl. XX, fig. 16; Börgesen, 1916, p. 93, figs. 99–101. Castle Island, Feb., Hervey.

G. SQUALIDA Kjellman, 1900, p. 55, Pl. VI, figs. 1–12; Pl. XX, fig. 9; Börgesen, 1916, p. 102, figs. 108–111; P. B.-A., No. 1882. Harris Bay and other points on the South Shore, at all seasons. In pools from half tide to low water, in dense tufts or often a much branched individual plant, about 10 cm. high, varying much in smoothness, firmness, and in density of branching; a favorite host for many species of small algae.

G. CYLINDRICA (Ell. & Sol.) Lamouroux, 1821, p. 22, Pl. XXII, fig. 4; Kjellman, 1900, p. 64, Pl. VIII, figs. 34–42; Pl. XX, fig. 53; Börgesen, 1916, p. 106; *Corallina cylindrica* Ellis & Solander, 1786, p. 114, Pl. XXII, fig. 4. Miss Wilkinson, a single specimen, without exact locality.

G. MARGINATA (Ell. & Sol.) Lamouroux, 1816, p. 264; Kjellman, 1900, p. 77, Pl. XX, fig. 44; Börgesen, 1916, p. 106, figs. 115–117; *Corallina marginata* Ellis & Solander, 1786, p. 115, Pl. XX, fig. 6; *Brachycladia marginata* P. B.-A., No. 1930. Near low water mark, Gravelly Bay, Jan., Hervey; at and below low water mark, Cooper's Island, Aug., Collins.

G. OBTUSATA (Ell. & Sol.) Lamouroux, 1816, p. 262; Kjellman, 1900, p. 88; P. B.-A., No. 1881; *Corallina obtusata* Ellis & Solander, 1876, p. 113, Pl. XXII, fig. 2. Faxon; Tucker's Town, Feb., Dec.; Walsingham, April, Hervey. Varies much in amount of calcification, which sometimes is entirely lacking. Usually there is not a gradual diminution of the amount of calcification, often the lower part of a frond is thickly calcified, this part sharply marked off from the upper part, quite uncalcified.

Family GELIDIACEAE.

Wrangelia Agardh.

W. penicillata Agardh, 1828, p. 138; Harvey, 1853, p. 143, Pl. XXXIV. B; Börgesen, 1916, p. 120, figs. 131–132; P. B-A., No. 1883. Rein; Kemp; Merriman, No. 5; Harris Bay, Jan., Castle Harbor, March, Tucker's Town, May, Harrington Sound near Flatts Bridge, Dec., Hervey; Shelly Bay, washed ashore, Hungry Bay, Nov., young plants only; dredged in 18 m. Nov., Collins. Abundant and luxuriant near Flatts Bridge from Dec. to Feb., seldom seen during the summer months.

Naccaria Endlicher.

N. corymbosa J. G. Agardh, 1899, p. 109; P. B.-A., No. 2036. Cooper's Island, Feb., Farlow; Buildings Bay, April, Hervey. Bornet, 1892, p. 266, incidentally refers to Farlow's specimens as *N. Wigghii;* comparison with the type specimen of *N. corymbosa* from Key West, in Agardh's herbarium, shows that the Bermuda plant is the same. Whether the differences between the American and the European plant are specific may require further study.

Gelidium Lamouroux.

1\. Basal layer well developed; erect shoots seldom over 2 cm. high. 4. G. pusillum.
1\. Basal layer scanty or wanting; erect shoots 5–50 cm. high. 2.
  2. Frond compressed or flat throughout, pinnate. 1. G. corneum.
  2. Frond terete, at least in the lower part. 3.
3\. Fruit in ovate terminal expansions. 2. G. crinale.
3\. Fruit in terminal expansions of irregular form, the edges dentate or ciliate. 3. G. spathulatum.

1\. G. corneum (Huds.) Lamouroux, 1813, p. 41; *Fucus corneus* Hudson, 1798, p. 585; Turner, 1819, p. 146, Pl. CCLVII, fig. a. Kemp, June, July. Two specimens in the Kemp herbarium resemble ordinary European forms; one is marked "var. k, *abnorme* Harvey" but is hardly like the figure in Turner for that variety. We have not ourselves found anything we should refer to this species.

2\. G. crinale (Turn.) Lamouroux, 1825, p. 191; P. B.-A., No.

2089; *Fucus crinalis* Turner, 1819, p. 4, Pl. CXCVIII. North Village, Dingle Bay, Jan., Hervey. A slender, irregularly branching form; the erect filaments are more flattened than in the common northern forms, and the branching is scanty, but there seems to be no better place for it than here.

3. G. SPATHULATUM (Kütz.) Bornet, 1892, p. 268; *G. crinale* var. *spathulatum* Hauck, 1885, p. 193, fig. 84; *Acrocarpus spathulatus* Kützing, 1868, p. 13, Pl. XXXVI, d–g. Harrington Sound, Feb., Hervey. Resembles *G. crinale*, but the upright fronds are terete except at the summit, where they are suddenly flattened; in the fruiting specimens numerous short branches arise here, making a tubercular mass, but always showing a distinct flattening.

4. G. PUSILLUM (Stack.) Le Jolis, 1863, p. 139; P. B.-A., No. 2182; *Fucus pusillus* Stackhouse, 1795, p. 16, Pl. VI. North Shore, Jan., Nov., Tucker's Town, Feb., Hervey; above and below Flatts Bridge, April, May, Aug., Collins. Tetraspores in March, April, Nov. Very common on pebbles, shells and flat rock bottom in shallow quiet water all about the islands, forming a dense mat, usually not over one cm. in thickness, the creeping basal part and the lower part of the upright growth terete, the upper part flat. As we understand this species, it includes *G. pulvinatum* (Kütz.) Thuret, and *G. repens* Kütz. Forms corresponding to Kützing's plates of both of these, as well as to typical *G. pusillum*, are found in Bermuda material, with all intermediate forms.

Var. CONCHICOLA Piccone & Grunow in Piccone, 1884, p. 316, P. B.-A., No. 2183, is a reduced form, common on small shells in shallow water; the upright fronds seldom reach 5 mm. high; they are mostly flat for their entire length, and only sparingly branched. But the same form occurs also on stones, and every intermediate can be found up to plants with erect fronds, 2 cm. high. Forms which we refer to *G. pusillum* occasionally occur in which the terete stipe expands into a flat frond, up to 5 cm. long and 3–5 mm. wide. This is very different in appearance from the usual form, but it intergrades so that it and var. *conchicola* must be regarded as extreme forms of a very variable species.

WURDEMANNIA Harvey.

W. SETACEA Harvey, 1853, p. 246; P. B.-A., No. 1887. A very common plant in quiet shallow water, all about the islands and dredged down to 18 m. It is quite variable in size, amount of ramification etc. It often forms dense mats, attached to the substratum by frequent rhizoids; at other times only the bases of the filaments are attached, the upper part forming loose tufts. Cystocarps and antheridia are unknown, tetraspores seldom occur, but were found in plants collected at Smith's Bay, Nov., Hervey. Short much branched forms might be mistaken for *Gelidium*, but on sectioning, the absence of the fine descending rhizoidal filaments of the internal layer is a sufficient distinction. *Gelidiopsis gracilis* Vickers, Algues de la Barbade, No. 126, seems to be this species; we have compared her specimen with an authentic specimen of *W. setacea* from the Harvey herbarium, and both with Bermuda material, and can find no differences.

FAMILY GIGARTINACEAE.

GIGARTINA Stackhouse.

G. ACICULARIS (Wulf.) Lamouroux, 1813, p. 48; Harvey, 1846–51, Pl. CIV; P. B.-A., No. 1884; *Fucus acicularis* Wulfen, 1803, p. 63. Kemp, June, as *G. Teedii;* Burchell's Cove, Feb., Gravelly Bay, April, Tucker's Town, March, May, Dec., Hervey; pool near Moore's calabash tree, April, Collins. Forming a somewhat matted coating on floors of caves or on bottoms of pools.

KALLYMENIA J. G. Agardh.

K. PERFORATA J. G. Agardh, 1871, p. 9; 1876, p. 219. Washed ashore, Cooper's Island, Feb., Farlow. There is much variability as to the amount of perforation; some fronds 6–7 cm. diam. are quite imperforate, while others, no larger, are little more than a network.

FAMILY RHODOPHYLLIDACEAE.

CATENELLA Greville.

C. OPUNTIA (Good. & Woodw.) Grev. var. PINNATA (Harv.) J. G. Agardh, 1876, p. 588; Alg. Am.-Bor. Exsicc., No. 149; P. B.-A., No. 1885; *C. pinnata* Harvey, 1853, p. 201, Pl. XXIX. B. Common between tide marks in quiet waters all about the islands, on ground, rocks and mangroves, usually in company with *Caloglossa Leprieurii*, species of *Bostrychia*, *Cladophoropsis membranacea* and the like. Cystocarps were found on plants collected near Flatts Bridge in August, Collins. The pinnate branching is usually quite manifest, but occasionally plants are found where it is not at all conspicuous; these are quite close to the typical *C. Opuntia* of Europe.

MERISTOTHECA J. G. Agardh.

M. DUCHASSAINGII J. G. Agardh, 1871, p. 36; 1879, Pl. XXXI, figs. 1–3. A single specimen among other algae collected March 4, 1911, Hervey, without exact locality. Evidently not common in Bermuda, as this one specimen, about 2 cm. high, is all that is recorded. It grows to a considerable size along the coast from Florida to North Carolina, specimens from Beaufort, N. C., reaching a length of 4 dm. It is usually very rough with short, stiff proliferations on the surface and margin, but occasionally it occurs quite smooth, when it is not so easily recognized. The difference is not one of maturity, as large smooth plants are found as often as small ones.

EUCHEUMA J. G. Agardh.

1.	Fronds flattened.	1. E. Gelidium.
1.	Fronds stout, subterete, very spinous.	2. E. denticulatum.

1. E. GELIDIUM J. G. Agardh, 1851, p. 627; 1876, p. 602; P. B.-A., No. 2184; *Sphaerococcus Gelidium* Kützing, 1869, Pl. XX. St. David's Island, Feb., Hervey, a few small plants only; South Shore, April, Collins.

2. **E. denticulatum** (Burm. f.) comb. nov.; *E. spinosum* J. G. Agardh, 1847, p. 16; *E. isiforme* Harvey, 1853, p. 118, Pl. XXIV; P. B.-A., No. 1886; *Fucus denticulatus* N. L. Burman, 1768, p. 28; *F. spinosus* Linnaeus, 1771, p. 313; Turner, 1808, Pl. XVIII. Rein; Moseley; April, May, June, Kemp; March, Wadsworth; Tucker, No. 14; Castle Harbor, Jan., Farlow; Bailey's Bay, Mrs. Hastings in Farlow herb.; Bailey's Bay, Jan., Gibbet Island, Jan., Cooper's Island, April, Devonshire Bay, Harris Bay, Dec., Hervey; Gravelly Bay, Tucker's Town, April, Aug., Collins. As may be inferred from the list of stations and collectors, this plant is plentiful and attractive. The living plant is of a dull red, and if prepared without exposure to

sun or air, the color darkens, sometimes becoming nearly black. But if the plant has grown where it is exposed to the full sunshine or if it has been exposed long to the air, the red becomes lighter and clearer, and later takes on a yellow shade. Exposure to the air for several days, if not in full sunshine, gives handsome color without disintegrating or decomposing the plant, if quite fresh when collected. It occurs in all sizes from 5 to 50 cm. high, and varies much in diameter of frond, frequency and regularity of branches, and especially as to the frequency, position and form of the conical or spinous ramuli. In the typical form these ramuli are arranged in whorls, distinctly separated, but forms occur, especially in old and large individuals, in which this whorled arrangement is hardly perceptible. The same differences occur in this species as found on the Florida coast, where it is common. At some stations in Bermuda a form occurs which we have not seen elsewhere; the frond is not over 10 cm. high, is relatively slender, but is so densely and so repeatedly branched that no trace of regularity is seen. This form was collected by Wadsworth in 1890, and has been found by us each year we have collected here. The American plant was described by Agardh, 1822, p. 271, as *Sphaerococcus isiformis;* J. G. Agardh, 1847, p. 16, proposed the new genus *Eucheuma,* including this and other species of *Sphaerococcus,* and the name has been continued since that time. Comparing the original description of *Sphaerococcus isiformis* with the species following, *S. spinosus,* the only distinctions of importance are, first that the former is described as "cartilagineo-gelatinosa" the latter as "gelatinoso-cartilaginea"; second, the former "papillulis ramorum verticillatis," the latter "papillulis solitariis, vel binis ternisve." The question of the distinctness of the two species was raised by Sonder, 1871, p. 60; under *E. spinosum* he notes that he found it with long, naked branches, also beset with papillae, either scattered or whorled. This alga is sold as an article of food in eastern countries, and most of the specimens that had then reached Europe were coarse forms obtained in the markets. J. G. Agardh, 1876, p. 601, referring to Sonder's criticism, says "Quae potissimum conveniunt, *E. spinosum* atque *E. isiforme,* stadio fructifero omnino diversae obvenerunt." But we find on *E. isiforme* fruit of the character attributed by him to *E. spinosum,* as well as that attributed to *E. isiforme.* Later, 1892, p. 12, in a revision of the genus, he uses vegetative characters, giving as the reason that the cystocarps were unknown to him on many of the species. Under *E. spinosum* he says "Icon Turneri tab. 18 pro suo tempore egregia." *E. isiforme* he considers as represented by Harvey's plate, 1853, Pl. XXIV, and the specimens distributed as Alg. Am.-Bor. Exsicc., No. 12. Turner's plate of *Fucus spinosus* was drawn from the specimen in the Linnean herbarium, and represents the type of the species. It has papillae partly whorled, partly scattered; there would be no trouble in matching it from Bermuda material, while Harvey's plate is quite typical of the ordinary, well developed plant. We think we are justified in discontinuing the name *E. isiforme.* But on referring to the original description of *Fucus spinosus,* Linnaeus, 1771, p. 313, we find that he gives as synonym "*F. denticulatus* Burm. prodr. 28".[13] Referring to that page we find the description "Caule compresso ramoso ramis dentato-geniculatis ramulosis subdichotomis." This, with the reference by Linnaeus, necessitates the new binomial we have used.

We have examined specimens from the Cape of Good Hope, Singapore and the Sunda Islands, quite indistinguishable from the American plant.

Family SPHAEROCOCCACEAE.

Gelidiopsis Schmitz.

G. rigida (Vahl) Weber, 1904, p. 9; P. B.-A., No. 2090; *Gelidium rigidum* var. *radicans* Alg. Am.-Bor. Exsicc., No. 142; *Fucus rigidus* Vahl, 1802, p. 46. Forms dense mats at and below low water mark, generally coarse and unattractive.

Gracilaria Greville.

1. Fronds stout, prostrate, attached to the substratum. 8. G. horizontalis.
1. Frond erect. 2.
  2. Frond plane. 3.
  2. Frond terete or compressed. 4.
3. Frond membranaceous, dichotomous, axils wide and rounded, apices obtuse. 7. G. dichotomo-flabellata.
3. Frond cartilaginous, axils acute, divisions tapering, acute. 6. G. multipartita.
  4. Branches long, filiform, slender. 1. G. confervoides.
  4. Branches not filiform. 5.

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[13] There is an error in the paging of this work; the pages run 1–28, then 25, 26, 27, 28, and thereafter correctly; the present reference is to the second p. 28.

5. Frond coarse, stout, branches mostly short and blunt. 5. G. Wrightii.
5. Frond less stout; many short, acute branches. 6.
  6. Branching corymbose; short acute branches near summit. 4. G. damaecornis.
  6. Short acute branches throughout. 7.
7. Frond pyramidal, branchlets dense, erect. 2. G. ferox.
7. Frond irregular, delicate, branches scattered, patent. 3. G. divaricata.

1. G. CONFERVOIDES (L.) Greville, 1830, p. 121; Harvey, 1846–51, Pl. LXV; *Fucus confervoides* Linnaeus, 1763, p. 1629. Kemp, a single plant of typical character; another specimen, marked *G. compressa*, is probably also *G. confervoides*.

2. G. FEROX J. G. Agardh, 1851, p. 592; 1876, p. 414; P. B.-A., No. 1932. Faxon; In shallow water, Moseley; Kemp; Rein, as *G. armata;* Dingle Bay, Inlet, Heron Bay, Jan., Grasmere, March, Hervey; Grasmere, Aug., Collins. Several species of the general appearance of *G. ferox* have been described, and it is by no means easy to separate them. There is a good deal of variety in the Bermuda forms we have included under this name, but they seem to agree in the terete but apparently distichously branched frond, with short acute branches, subsecundly placed. We have found it quite common in warm shallow water, such as the lagoons near Grasmere and Fairyland.

3. G. DIVARICATA Harvey, 1853, p. 109. Mrs. S. A. Boggs; Bailey's Bay, Feb., Wadsworth; reported by Kemp, but no specimen found in his herbarium. The two specimens we have seen agree well with Harvey's description, and there seems no other place for them. The habit is much like that of *Ochtodes filiformis* J. Ag., and the latter species, from Jamaica, was erroneously distributed as *G. divaricata* in P. B.-A., No. 789. The *Ochtodes* has an articulated filamentous axis which is not found in *Gracilaria.*

4. G. DAMAECORNIS J. G. Agardh, 1851, p. 597; 1876, p. 415. In shallow water, Grasmere, Aug., Collins; Miss Wilkinson. As we understand this species, it is stouter than *G. ferox*, drying very hard and firm; the branching is more regularly dichotomous, the ramuli short and subulate, near the ends of the branches. We have found it once only, when it grew among *G. ferox*, but could be distinguished from the latter by its appearance, even as seen from the boat.

5. G. WRIGHTII (Turn.) J. G. Agardh, 1851, p. 599; *Fucus Wrightii* Turner, 1811, Pl. CXLVIII; including *G. Poitei* J. G. Agardh, 1851, p. 596 and *G. cornea* J. G. Agardh, 1851, p. 598. Castle Harbor, Feb., Farlow; Elbow Bay, Dec., Collins. We have carefully examined

a large amount of material from the Florida-West India region, including specimens determined by J. G. Agardh, and can find no line of demarcation between the three species mentioned. *Fucus Poitei* Lamouroux, 1805, Pl. XXX, figs. 2–3, antedates *F. Wrightii*, but now proves to be a *Laurencia*, and the next oldest name is Turner's which we adopt. It includes most of the coarse, fleshy or cartilaginous Gracilarias of the warmer Atlantic; probably always terete when alive, but often appearing compressed in herbarium material. It is not common at Bermuda.

6. G. MULTIPARTITA (Clem.) Harvey, 1846–51, Pl. XV; *Fucus multipartitus* Clementi, 1804, p. 311. Kemp, July, two specimens in herb.; Building's Bay, Feb., one small frond, Hervey.

7. G. DICHOTOMO-FLABELLATA Crouan in Mazé & Schramm, 1870–77, p. 218. Mrs. Boggs, 1895; St. David's Island, Feb., May, South Shore, April, Hervey; tetraspores in May. This species varies considerably in color and texture, from thin membranaceous and clear red to subcartilaginous and brownish. In the former case the shape and subdivision of the frond are indicated by the specific name; in the latter the division is more irregular. The Bermuda plant as a rule has a thinner frond and narrower segments than the Florida material distributed as P. B.-A., No. 334. We were at first inclined to identify this plant with *G. Textorii* (Suringar) Hariot, 1891, p. 223, *Sphaerococcus Textorii* Suringar, 1870, p. 36, Pl. XXIII, and a specimen from Province Boshu, Japan, for which we are indebted to the kindness of Dr. K. Yendo, has much resemblance to the Bermuda plant. But the plant figured by Okamura, 1901, p. 65, Pl. XXIII, and distributed in his Algae Japonicae Exsiccatae No. 13, differs considerably, having a habit more like the common little divided forms of *Rhodymenia palmata*. Our plant agrees with Crouan's species, as represented by an authentic specimen in the Museum d'Histoire Naturelle, at Paris, and it has seemed to us better on the whole to retain for the present Crouan's name, under which the plant had already been distributed in P. B.-A. J. G. Agardh, 1889, p. 25, refers to *G. dichotomo-flabellata* as a possible synonym of *Chrysymenia halymenioides* Harvey, mentioning *Chrysymenia dichotomo-flabellata* Crouan as perhaps the same; the latter has been distributed as P. B.-A., No. 385; it is probable that it is, as suggested by J. G. Agardh, a form of *Chrysymenia halymenioides*, but the plant distributed as P. B.-A., Nos. 334 & 1931 is certainly a *Gracilaria*. The following short diagnosis, in connection with the material distributed as P. B.-A., Nos. 334, 1931, will probably give a sufficient idea of the species.

Gracilaria dichotomo-flabellata Crouan in Mazé & Schramm, Algues de la Guadeloupe, p. 218, without description. A disco parvo, stipite brevi subtereti vel compresso, mox in frondem planam regulariter dichotomam abeunte, segmentis linearibus 5 mm. ad 2 cm. latis, apicibus obtusis vel truncatis; axillis latis, rotundatis; substantia membranacea, juniore tenuiore, adultiore crassiore et firmiore; colore laete- vel fusco-rubro; tetrasporangiis sparsis; cystocarpiis magnis, ad superficiem utrinque sparsis.

8. **G. horizontalis** sp. nov. Fronde a disco centrali irregulari horizontaliter expansa, ramis quoquoversum exeuntibus, subteretis, crassis, ramos ferentibus densissimos, minime attenuatos; cellulis interioribus magnis, corticem versus minoribus, cortice submonostromatico, cellularum minutarum coloratarum. Fructificatione ignota.

Frond expanding horizontally from a central irregular disk, emitting on all sides very densely set branches, tapering very little; interior cells large, becoming smaller towards the submonostromatic cortex, which is formed of small colored cells. Fructification unknown.

The habit is unique in the genus; the plant seems to creep over the bottom of the pool in which it grows, much in the same way as do the haptera of a *Laminaria;* the tips of the branches, or short projections on the margins or lower surface, adhering to the substratum quite firmly. If a young but vigorous frond of *Laminaria* were cut off at the base of the stipe, just at the level of the upper haptera, the remaining basal part would give a good idea of the appearance of this species. Plants growing together are almost inextricably entangled, and even when a plant is not in contact with others, it is difficult to detach it. The substance is tough and cartilaginous, the color of the more or less wrinkled surface is dull yellowish brown, but the lower part, not exposed to the light, is of the clear purplish red found in other species of Gracilaria. It was found in rock pools at low water mark at Gravelly Bay, Aug. 27, 1913, Collins. Type in Collins herb., No. 7818. Since found at the same station in Feb. and April, at Harris Bay, April, Hervey.

HYPNEA Lamouroux.

1. Branches long, virgate, often with hooked tips. 1. H. musciformis.
1. Branches not virgate, no hooked tips. 2.
    2. Forming a low, dense, matted expansion. 3. H. spinella.
    2. Erect fronds from a matted base, slender, with patent ramuli. 2. H. cervicornis.

1. H. MUSCIFORMIS (Wulf.) Lamouroux, 1813, p. 43; Hauck, 1885, p. 188, fig. 81; P. B.-A., No. 2185; *Fucus musciformis* Wulfen in Jacquin, 1789, p. 154, Pl. XIV, fig. 3. Rein; Kemp; Miss Peniston; Dingle Bay, Bailey's Bay, Jan., St. David's Island, Feb., Grasmere, March, Buildings Bay, Heron Bay, April, Hervey; Hungry Bay, April, Cooper's Island, Aug., Collins. Generally distributed; the well developed plants with long, virgate branches, beset with short ramuli, and with tips hooked, are not to be mistaken for anything else, but young and stunted forms are hard to distinguish from other species of the genus.

Wulfen's type was from Trieste, where he found the plant growing on crabs for sale in the fish market. His plate is excellent, and shows a slender form with filiform ramuli, often with constricted bases. We have seen similar plants from the Mediterranean and the Adriatic, and on the American shore from Cape Cod to Florida and the West Indies. A form different in appearance has been distributed by Bornet, collected at Biarritz; it is stouter, the ramuli shorter and more patent, and mostly with distinctly wider base, in dried specimens often like rose thorns; hooked tips are very rare in this form, common in the other. This form we have seen from various parts of the Atlantic coast of France, and on the American coast from Beaufort, N. C., to Florida and the West Indies. The two extreme forms are distinct in appearance, though less characteristic forms can be found. Sterile plants can be found in both, but as far as we have observed, cystocarpic plants usually have all the ramuli of the thorn-like type, always some ramuli of this form; while tetrasporic plants have the filiform ramuli with base ultimately constricted. The appearance of the two types is so different that in Agardh's treatment of the genus, 1851, p. 441, the former would come under Sect. I, Virgatae, "ramulis adultioribus basi constrictis," the other, p. 446, Sect. Spinuligerae, "ramulis subulatis, a basi latiore acuminatis." Both forms occur in Bermuda.

2. H. CERVICORNIS J. G. Agardh, 1851, p. 451; 1876, p. 564. Miss Peniston; Old Ferry, April, Hervey. This lacks the hooked apices of *H. musciformis*, and is a more slender and more densely branched plant; but the line between the two species is by no means clear.

3. H. SPINELLA (Ag.) J. G. Agardh, 1847, p. 14; *Sphaerococcus spinellus* Agardh, 1822, p. 323. Cave by Gravelly Bay, Apr., Hervey. Forming a dense, inextricable mat on rocks, usually 1–2 cm. thick.

There is probably no genus of red algae of this region the species of which are so poorly defined, and the plants so little characteristic, as

Hypnea. Well developed plants of *H. musciformis* are easily recognized, but practically everything else is vague and doubtful, and our determinations of other species are only tentative. In regard to the smaller forms, it seems as if no two authors used the same name for the same plant, and even the best authors are often inconsistent with themselves. For instance, J. G. Agardh, 1876, p. 564, under *H. cervicornis,* refers to *H. spinella* Kützing, 1868, Pl. XXVI, as a synonym; under *H. spinella* (Ag.) J. Ag., on the next page, he refers to the same plate. We have collections of *Hypnea* from several stations to which we do not feel willing to give specific names. *H. cornuta* reported by Moseley proves to be *Chondria polyrhiza* Collins & Hervey.

Family RHODYMENIACEAE.

Cordylecladia J. G. Agardh.

C. rigens (Ag.) comb. nov.; P. B.-A., No. 2186; *C.? irregularis* Harvey, 1853, p. 156; *Sphaerococcus rigens* Agardh, 1822, p. 332; *Chylocladia rigens* J. G. Agardh, 1851, p. 362. In dense matted tufts between tide marks, Harrington Sound, Feb., Farlow; Fairyland, Dec., Collins. Comparison with authentic specimen of *Chylocladia rigens* shows the identity with Harvey's species, and the fructification, see Collins, 1901, p. 255, is that of *Cordylecladia.*

Chrysymenia J. G. Agardh.

1. Frond with solid terete stipe and vesicular ramuli. 2.
1. Frond without solid stipe. 3.
  2. Branches long, virgate, with spherical or ovoid ramuli. 4. C. uvaria.
  2. Branches short, stout, with larger, pyriform ramuli. 5. C. pyriformis.
3. Frond tubular, branches proliferous with constricted base. 3. C. Enteromorpha.
3. Frond compressed, dichotomous or irregularly cleft. 4.
  4. Frond slender, divisions linear. 2. C. halymenioides.
  4. Frond broader, divisions lanceolate or ovate. 1. C. Agardhii.

1. C. Agardhii Harvey, 1853, p. 189, Pl. XXX. A. Cooper's Island, Feb., Farlow; shallow water, Moseley. Apparently rare, as

neither of us has found it. In Kemp's list mention is made of *Chylocladia rosea.* No specimen with that name is to be found in his herbarium; the species is northern in its range, and not likely to occur here; some forms of *Chrysymenia Agardhii* have habitual resemblance to *Chylocladia,* and may have been the basis for this record.

2. C. HALYMENIOIDES Harvey, 1853, p. 188, Pl. XX. A. One very small plant, Moseley.

3. C. ENTEROMORPHA Harvey, 1853, p. 187. Dredged in 60 meters on Challenger Bank, Aug., 1903, Berm. Biol. Sta.

4. C. UVARIA (L.) J. G. Agardh, 1842, p. 106; Harvey, 1853, p. 191, Pl. XX. B; P. B.-A., No. 1933; *Fucus uvarius* Linnaeus, 1767, p. 714. Rein; Kemp; Moseley; Faxon; Walsingham, Jan., March, Hervey, April, Collins. Appears to grow chiefly in sheltered places among rocks, and may be more common than would appear from the single locality in which we have found it.

5. C. PYRIFORMIS Börgesen, 1910, p. 187, figs. 8–9. A single, well-developed plant, on the perpendicular wall of a "chasm" near Tucker's Town, below low water mark, April, Collins.

COELARTHRUM Börgesen.

C. ALBERTISII (Piccone) Börgesen, 1910, p. 189, figs. 11–12; P. B.-A., No. 2091; *Chylocladia Albertisii* Piccone, 1884a, p. 37, figs. 3–5. Attached to Corallines, Ducking Stool, Jan., Farlow; floating off Cooper's Island, Feb., Farlow; Miss Wilkinson; Shore of Gibbet Island, Jan., Feb., North Shore, March, washed ashore, Buildings Bay, Feb., Hervey; dredged in 18 m., Nov., Collins. This species was founded on a single specimen collected at the Canaries, 1882; a single specimen with the ms. name *Chrysymenia Lomentaria* Crouan is in the Thuret herbarium at Paris; it was dredged once, in about 30 meters, in March, in the Danish West Indies; these are the only records outside of Bermuda. In January and February small plants are found among the roots of *Sargassum,* seldom over 1 cm. high; the larger plants are found washed ashore, probably from deep water. These plants were packed together in crisp masses, with rounded surfaces, like the masses of *Valonia macrophysa,* but on a smaller scale. No fruit was found on the specimens of our collecting, but there were cystocarps on those collected by Farlow in February, tetraspores on those collected by Börgesen in March; both are figured by Börgesen.

LOMENTARIA Gaillon.

L. UNCINATA Meneghini in Zanardini, 1840, p. 21; Farlow, 1881, p. 154. Miss Wilkinson; Walsingham, Jan., Hervey. Rather small plants.

Var. FILIFORMIS (Harv.) Farlow, 1881, p. 155; *Chylocladia Baileyana* var. *filiformis* Harvey, 1853, p. 185, Pl. XX. C, fig. 2. Very small plants among *Polysiphonia macrocarpa*, on mangroves, Hungry Bay, May, Collins.

CHAMPIA Desvaux.

C. PARVULA (Ag.) Harvey, 1853, p. 76; P. B.-A., No. 1934; *Chondria parvula* Agardh, 1824, p. 207; *Chylocladia parvula* Harvey, 1846–51, Pl. CCX. Gibbet Island, Jan., Heron Bay, April, Hervey; Gibbet Island, Sept., Fairyland, Dec., Collins. On *Sargassum*, *Coelarthrum* and other algae; mostly with tetraspores; small plants, seldom over 3 cm. high.

FAMILY DELESSERIACEAE.

NITOPHYLLUM Greville.

N. Wilkinsoniae sp. nov.; P. B.-A., No. 2037. Frondes usque ad 10 cm. altae, dense di- polychotomae, divisionibus linearibus cuneatisve, latitudine centimetrum raro superantibus; marginibus dentes minutas ciliiformes plus minusve approximatas ferentibus; venis nullis; fronde monostromatica, juniore 15 μ crassa, adultiore usque ad 60 μ; cellulis in superficiem visis irregulariter polygonis, 30–80 μ diam.; in sectione transversali junioribus elongatis, adultioribus subquadratis. Tetrasporangiis tripartitis, ad 60 μ diam., soris rotundatis vel elongatis per totam frondem sparsis, utrinque prominulis; cystocarpiis ignotis; substantia tenuissima; fronde viva, colore malvacea; emersa cito in aurantiacam mutata; siccata rosea. Plate I, fig. 8, Plate II, fig. 9, Plate V, figs. 32–33.

Fronds up to 10 cm. high, densely tufted, di- polychotomously divided, divisions linear or cuneate, seldom over one cm. wide, margin more or less densely set with small ciliform teeth; no veins; monostromatic, 15 μ thick in the younger part, up to 60 μ in older parts; cells regularly polygonal in superficial view, 30–80 μ diam., in cross section, elongate in younger, squarish in older parts. Tetraspores tripartite, up to 60 μ diam., densely packed in small roundish or oval sori, generally distributed over the frond, slightly projecting on both surfaces; cystocarps unknown. W. Faxon; Miss Wilkinson; Harrington Sound, Ducking Stool, Feb., Farlow; Dingle Bay, April, caves at Tucker's Town, May, Collins. On rocks below low water mark; forming dense masses, crisp when first taken from the water, but soon softening into a shapeless mass. The branching is so dense and the substance so tender that it is difficult to disentangle individual plants. When growing the color is mauve, on exposure changing almost instantaneously to orange; when mounted on paper lake or rosy red. In habit like *N. marginatum* Harvey, Ceylon Algae No. 26, but that species lacks the ciliiform teeth, and has somewhat smaller cells but larger tetraspores, which are in less dense sori, and tend to form a confluent marginal band. A specimen of *N. venulosum* Zan., from Trieste, leg. Hauck, also resembles *N. Wilkinsoniae,* but has more slender segments, less densely branched and tufted, and distinct though microscopic veins.

HYPOGLOSSUM Kützing.

H. hypoglossoides (Stack.) comb. nov.; *H. Woodwardi* Kützing, 1843, p. 444, Pl. LXV, fig. 1; *Delesseria Hypoglossum* Harvey, 1846–51, Pl. II; *Fucus hypoglossoides* Stackhouse, 1795, p. 76, Pl. XIII. Jan., 1912, a single specimen, without exact locality, Hervey. The rather unfortunate combination we now use for the first time, appears to be required by the international rules.

CALOGLOSSA J. G. Agardh.

C. LEPRIEURII (Mont.) J. G. Agardh, 1876, p. 499; P. B.-A., No. 2038; *Delesseria Leprieurii* Montagne, 1840a, p. 196, Pl. V, fig. 1; Harvey, 1853, p. 98, Pl. XXII. C. Among other algae on mangroves and other objects between tide marks, less commonly pure or nearly so. Farlow; Burchell's Cove, Feb., Ely's Harbor, Dingle Bay, April, Hervey; Hungry Bay, May, Collins. Tetraspores in April. The Bermuda material corresponds to *C. mnioides* J. G. Agardh, 1876, p. 500,[14] the segments being ovate, sometimes quite broadly so, and the

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[14] Later, 1898, p. 235, J. G. Agardh intimates that most of the described species of the genus may be only forms, depending on locality. This appears to be his latest expression of opinion on the subject.

cells in the membrane narrowly rectangular, in quite distinct series to the margin. Compared with the very narrow form from brackish water at West Point, New York, the distinctness of species seems justified, but intermediate forms occur, some from Florida having as wide segments as the Bermuda plant, but with polygonal or rhomboidal cells in indistinct series. The variation can hardly be due to climate, as a specimen of Miss Vickers, Algues de la Barbade, No. 144, has fronds as narrow as in the plant of Long Island Sound and Hudson River.

Taenioma J. G. Agardh.

T. perpusillum J. G. Agardh, 1863, p. 1257; *T. macrourum* Thuret in Bornet & Thuret, 1876, p. 69, Pl. XXV; P. B.-A., No. 1935; *Polysiphonia perpusilla* J. G. Agardh, 1847, p. 16. In a gelatinous mass among small algae, Gibbet Island, April, Hervey. Tetraspores were common in this material; a single mature cystocarp was found, but unfortunately was lost before notes and figures could be made.

Family BONNEMAISONIACEAE.

Asparagopsis Montagne.

A. taxiformis (Delile) comb. nov.; *A. Delilei* Montagne, 1840, p. XIV; *Dasya Delilei* Montagne, 1840, p. 166, Pl. VIII, fig. 6; *Fucus taxiformis* Delile, 1813, p. 151, Pl. LVII, fig. 2. Merriman; Cooper's Island, Feb., Farlow. Apparently rare, as we have not met with it, nor have we found it in any other collections than as above. As Montagne refers to *Fucus taxiformis* Delile, but changes the specific name to do more honor to the author, the original name must be restored according to the international rules.

Family RHODOMELACEAE.

Laurencia Lamouroux.

1. Ultimate ramuli short, often tubercle-like. 2.
1. Ultimate ramuli longer. 3.
   2. Ultimate ramuli distant, simple. 2. L. Poitei.
   2. Ultimate ramuli densely set, mostly lobed. 3. L. papillosa.

3. Frond decumbent, rooting, densely matted.	1. L. perforata.
3. Frond erect.	4.
4. Outline of frond and of main divisions narrowly pyramidal.	5.
4. Outline broader.	6.
5. Slender, 3 or 4 cm. high.	5. L. obtusa var. gelatinosa.
5. Stout, 1–2 dm. high.	6. L. paniculata.
6. Branching mostly opposite or whorled.	5. L. obtusa.
6. Branching subdichotomous, corymbose.	4. L. cervicornis.

1. **L. perforata** Montagne, 1860, p. 155; Kützing, 1865, p. 18, Pl. XLIX, figs. e–g; P. B.-A., No. 1889. Bailey's Bay, Jan., Harris Bay, Jan., Nov., Gravelly Bay, Oct., Hervey; Tucker's Town, May, South Shore, Aug., Collins. This species occurs not uncommonly in caves and potholes, where it forms dense matted masses, the filaments adhering to the rock and to each other by numerous holdfasts. The surface of the mass sometimes has an iridescence of remarkable brilliancy, chiefly in metallic blues and greens. The iridescence is on the upper surface only, and persists for a short time after the plant is taken from the water.

2. **L. Poitei** (Lamour.) M. A. Howe, 1905, p. 583; *L. tuberculosa* J. G. Agardh, 1852, p. 760; P. B.-A., No. 1937. *L. gemmifera* Harvey, 1853, p. 72, Pl. XVIII. B.; *Fucus Poitei* Lamouroux, 1805, p. 63, Pl. XXXI, figs. 2–3. Harrington Sound, Farlow; Cooper's Island, a slender form, Wadsworth; Heron Bay, April, Hervey; Fairyland, July, Collins. In warm shallow water, where it forms loose-lying masses in warm weather. *L. tuberculosa* has been described by J. G. Agardh as "fronde compressa distiche decomposito-pinnata," but it may well be that the compression and distichous branching in Agardh's plant are due to the manner of preparation; the Bermuda plant has no such characters.

3. **L. papillosa** (Forsk.) Greville, 1830, p. LII; P. B.-A., No. 1936; *Fucus papillosus* Forskäl, 1775, p. 190. Castle Harbor, Farlow; Harris Bay, Jan., Heron Bay, April, Hervey; Jew's Bay, July, Cooper's Island, Harrington Sound, Aug., Collins. Quite common and usually easily recognizable.

4. **L. cervicornis** Harvey, 1853, p. 73, Pl. XVIII. C; P. B.-A., No. 2187. Wadsworth, No. 19; Miss Wilkinson; Cooper's Island, April, Aug.; dredged in 4 m., Dec., Collins; Buildings Bay, April, St. David's Island, May, Hervey. This species appears to be little known to European botanists; De Toni, 1903, p. 781, gives it as a synonym under *L. implicata*, but it is certainly not the *L. implicata* of Harvey, 1853, p. 72, Pl. XVIII. D., fide authentic specimens. *L.*

cervicornis has a frond of rounded outline, branching subdichotomous, distant below, increasingly close upward; all branches, long or short, are of about the same diameter, about that of the main axis of a frond of *L. obtusa*, medium size. Proliferous ramuli, very short, may be abundant or nearly or quite wanting. It is found in rather sheltered stations, the color a somewhat deep and translucent red in the living plant, growing darker in the mounted specimen. It usually adheres fairly well to paper.

5. L. OBTUSA (Huds.) Lamouroux, 1813, p. 42; Harvey, 1846–51, Pl. CXLVIII; P. B.-A., No. 2092; *Fucus obtusus* Hudson, 1798, p. 586. A very common and variable species, occurring nearly everywhere in quiet water, and often in somewhat exposed places, and dredged to a depth of 18 m. The genus *Laurencia* is very puzzling; though typical forms can be found of all the species, intermediate forms are equally common, and it is very difficult to draw any sharp lines. Of what may be considered the typical form of *L. obtusa* there are two varieties, differing sharply in color, but not otherwise; one is reddish or yellowish brown, lighter where exposed to sunshine, darker below; the other a light, glaucous blue-green. They grow in similar stations; often, as in the lower part of Harrington Sound, both are found together, but as separate individuals or tufts; we have seen no intermediate forms under these conditions.[15] Beside the typical form, two varieties may be noted.

Var. GRACILIS Kützing, 1865, p. 20, Pl. LIV, figs. c and d; *L. dasyphylla* Kemp, in herb. A delicate, soft and slender form.

Var. GELATINOSA (Desf.) J. G. Agardh, 1852, p. 751; P. B.-A., No. 1888; *Fucus gelatinosus* Desfontaines, 1798, p. 427. Mrs. Hastings; Spanish Rock, Jan., Gravelly Bay, March, Dec., Hervey. Tetraspores in Jan. A low and slender form of exposed rocky shores; in spite of its name it is firmer and less adherent to paper than *L. obtusa*, typical. In connection with *L. obtusa* we have found forms near to *L. setacea* Kützing, 1848, p. 854; *L. intricata* Kützing, 1865, Pl. LXI, figs. a-c,[16] but they shade into the typical *L. obtusa* so plainly, and in no

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[15] It is of interest to note that practically the same forms occur at Naples; see Falkenberg, 1901, p. 247. "Um Neapel, wo die Pflanze das ganze Jahr hindurch zu den gemeinsten Formen gehört, kommt sie in zwei Varietäten vor, welche, im übrigen gleich, durch ihre Färbung sich wesentlich unterscheiden, die eine ist gelbrothlich, die andere grünlich. Beide Formen treten gesondert in unregelmässig durch einander gewirrten Rasen an den gleichen Standorten auf."

[16] *L. intricata* Lamouroux, 1813, p. 43, Pl. IX, figs. 8–9, is nomen nudum, hence Kützing's name of 1848 has priority.

case are they quite typical *L. setacea*, that it seems best to consider them merely forms of the common and variable *L. obtusa*. A specimen in the Farlow herbarium, collected by G. Tucker, No. 10, is near *L. implicata* J. G. Agardh, 1852, p. 745, and a similar form was found on the outer reef, Ely's Harbor, July, Collins, and this also we have considered as a local form of *L. obtusa*. This form is found rather commonly when dredging.

6. L. PANICULATA (Ag.) J. G. Agardh, 1852, p. 755; *Chondria obtusa* var. *paniculata* Agardh, 1822, p. 343. Faxon; Dingle Bay, Jan., Buildings Bay, Mangrove Bay, Feb., Hervey. Connected by intermediate forms with *L. obtusa*, but in its typical form quite distinct by the firmer, little adhesive substance, the narrowly pyramidal form of the frond and of its principal divisions, the main axis distinctly projecting.

CHONDRIA Agardh.

1\. Rhizoids frequent; tetraspores in specialized branches. 4. C. polyrhiza.
1\. No rhizoids except at extreme base; tetraspores in normal branches. 2.
  2\. Ends of pericentral cells showing as a wavy line across the frond. 1. C. curvilineata.
  2\. Pericentral cells not showing externally. 3.
3\. Ramuli acute or subacute. 3. C. atropurpurea.
3\. Ramuli blunt or truncate. 2. C. dasyphylla.

1. **C. curvilineata** sp. nov.; P. B.-A., No. 2039. Fronde tenui, axibus principalibus diametro ½ mm. raro superantibus, ramos paullo minores paucos pluresve alternantes ferentibus, ordinum duorum, raro plures, cylindricos vel ad basin et apicem paullo contractos; puncto vegetationis ad fundo foveae apicalis, folia brevia ferente; foliis similibus secundum ramos sparsis; segmentis diam. duplo longioribus; cellulis corticalibus diam. duplo longioribus; apicibus cellularum centralium per corticem manifestis ut lineis curvis, latere convexo apicem versus; cystocarpiis sessilibus; substantia submolli; colore rubro obscuro. Plate II, figs. 10–11.

Frond slender, main axes seldom reaching ½ mm. diam., with more or less numerous alternate branches of two orders, seldom more, of only slightly less diam., cylindrical or slightly contracted at base and apex; growing point at bottom of an apical pit, with a tuft of short leaves, similar leaves occurring also at scattered points on branches; segments about 2 diam. long; cortical cells about twice as long as broad; swollen apices of pericentral cells showing through the cortication as rounded lines, the convex side towards the apex of the branch; cystocarps sessile on the branches; no other organ of fructification observed; color dull red; substance rather soft. Type specimen in Collins herbarium, No. 7509, Heron Bay, April 19, 1913, Hervey; also at St. David's Island, Feb., near Wistowe, Dec., Hervey.

This plant belongs to the subgenus *Coelochondria* Falkenberg, but is distinct from all but one of the species of the subgenus by the peculiar transformation of the upper ends of the pericentral cells, which show even under a slight magnification as curved lines, two or three showing in the width of the branch. This same character is found in *C. succulenta* (J. Ag.) Falkenberg, 1901, Pl. XXII, figs. 22–23, an Australian species, but that is a large and fleshy plant. In some specimens of *C. curvilineata* this character is less conspicuous than in others, but it is always quite distinct at the base of a branch, where the cortication is thin.

2. C. DASYPHYLLA (Woodw.) Agardh, 1822, p. 350; *Fucus dasyphyllus* Woodward, 1794, p. 239, Pl. XXIII, figs. 1–3; *Laurencia dasyphylla* Harvey, 1846–51, Pl. CLII. St. David's Island, May, Hervey. A single plant, well developed and typical.

3. C. ATROPURPUREA Harvey, 1853, p. 22, Pl. XVIII. E. Heron Bay, March, Hervey. A single, quite typical plant.

4. **C. polyrhiza**, sp. nov.; P. B.-A., No. 2040. Fronde tenui, axi principali diametrum $\frac{1}{2}$ mm. raro attinente, ramos paullo minores paucos pluresve alternantes ferente, ramulis secundi vel tertii ordinis minoribus brevioribusque, ad basin plus minusve contractis, prope apices conicos foliis brevibus deciduis armatis; ramis ordinum omnium plus minusve flexuosis; cellulis corticalibus linearibus, longitudine latitudinem 3–4-plo superante; tetrasporis in ramulis ultimis, partis fertilis margine subdentato, apice breviacuto; basi a parte inferiori sterili ramuli evidenter distincto, parte fertili diametro partem sterilem duplo superante; segmentis per corticem tantum in parte extrema juvenili manifestis; rhizoideis brevibus unicellularibus in fasciculis densis ex partibus omnibus frondis exeuntibus; substantia subfirma; colore rubro pallido. Plate II, fig. 12.

Frond slender, main axis seldom reaching $\frac{1}{2}$ mm. diam., with more or less numerous, alternate patent branches of slightly less size, with one or two orders of smaller and shorter branches with more or less contracted bases, and with tufts of short, fugacious leaves near the tapering apices; branches of all orders more or less flexuous; cortical cells linear, 3–4 times as long as wide; tetraspores in ultimate ramuli, the fertile portion showing a subdentate outline, the apex short-pointed, the base sharply distinct from the lower sterile part of the ramulus, which is usually about half the diam. of the fertile part; segments of pericentral cells showing indistinctly through the cortication in the youngest portions only; dense fascicles of short, unicellular rhizoids issuing from all portions of the plant; color pale red; substance rather firm. Type in Collins herbarium, No. 8007, Shelly Bay, Jan. 10, 1913, Hervey; also at North Shore near Wistowe, Jan., Feb., Hervey; dredged in 18 meters, Dec., Collins.

The cylindrical fronds and the absence of apical pits place this plant in the subgenus *Euchondria* Falk.; the abundant rhizoids are of the same type as in the genus *Herpochondria,* but there is neither the dorsiventral structure nor the lateral adherence of the latter. The rhizoids may occur in short cylindrical fascicles, or may form a dense mass along the frond for a distance equal to several diameters; they may occur on branches of any order, even on the stichidia with mature tetraspores.

ACANTHOPHORA Lamouroux.

A. SPICIFERA (Vahl) Börgesen, 1910, p. 204, figs. 18–19; P. B.-A., No. 1938; *A. Thierii* Harvey, 1853, p. 17, Pl. XIV. A; *Fucus spiciferus* Vahl, 1802, p. 44. Aug., Kemp; Rein; Tucker, No. 13; Walsingham, Farlow; common in quiet waters generally, Jan., March, Oct., Hervey; April, May, July, Aug., Collins. In July and August lying loose on the bottom, but continuing to grow. On submerged tips of live Tamarisk branches, Harrington Sound, Aug., Collins.

FALKENBERGIA Schmitz.

F. HILLEBRANDI (Born.) Falkenberg, 1901, p. 689; Börgesen, 1910, p. 199, fig. 17; P. B.-A., No. 2043; *Polysiphonia Hillebrandi* Bornet in Ardissone, 1883, p. 376. Growing in matted tufts on various algae; Miss Peniston; cave by Ducking Stool, April, cave, Gravelly Bay, Aug., Dec., Gibbet Island, Aug., Bethel's Island, Dec., Collins; Harrington Sound, Oct., Nov., Dec., cave, Gravelly Bay, Dec., Hervey. In the plants collected at Gravelly Bay in December, were found tetraspores, which have not before been recorded for the species; they are tripartitely divided, and formed from one of the pericentral cells of a ramulus, quite as in *Polysiphonia,* but occurred singly, not in series.

POLYSIPHONIA Greville.

1. Pericentral cells 4. 2.
1. Pericentral cells more than 4. 4.
  2. Forming low, dense, more or less even-topped tufts or mats. 2. P. macrocarpa.
  2. Taller, more open in growth. 3.
3. Segments seldom over 1 diam. long; tetraspores in densely forking, divaricate ramuli. 4. P. ferulacea.
3. Segments in main axis usually over 1 diam. long; tetraspores near tips of normal branches. 1. P. havanensis.
  4. Pericentral cells 8–13; soft and dense. 3. P. foetidissima.
  4. Pericentral cells 20–24 in main axis; firmer. 5. P. opaca.

1. P. HAVANENSIS Montagne forma MUCOSA J. G. Agardh, 1863, p. 960; P. B.-A., No. 1941; *P. havanensis* Harvey, 1853, p. 34. Spanish Rock, April, floating by Causeway, Oct., Inlet, Oct., St. George's Bay, Dec., Hervey. On *Penicillus, Halimeda, Sargassum* etc.; cystocarps in April. Fairyland, Dec., Collins. The fine soft filaments and rich red-brown color are characteristic of this form; the segments vary from one to four diam. long in the same plant. The cystocarps are globose below, broadly urceolate above. The leaves are long and much branched; normal branches are formed in their axils.

2. P. MACROCARPA Harvey in Mackay, 1836, part 2, p. 206; P. B.-A., No. 2093; *P. pulvinata* Harvey, 1846–51, Pl. CII. B, not of J. Ag. On mangroves, with *Dichotomosiphon pusillus* etc., Hungry Bay, May, Collins. Forming a close and rather dense coating. The filaments resemble *P. subtilissima* Mont., but are more slender, and the habit is quite different. An account of the distinction between this plant and the original *P. pulvinata* (Roth) J. Ag. will be found in Bornet, 1892, p. 306. Our plant is more slender than the European but otherwise the same.

3. P. FOETIDISSIMA Cocks in Bornet, 1892, p. 314; British Seaweeds, No. 29; P. B.-A., No. 1890. On timbers by sea wall at Hamilton, Jan., on stones on beach at St. George's, April, Hervey; cystocarps and tetraspores in Jan. An apparently little known species, but quite well marked. The filaments have 8–10, rarely to 13 pericentral cells, are creeping at the base, then erect, much branched, reaching a height of 15 cm. The substance is soft, the color deep purplish red. It decays promptly when taken from the water, and then thoroughly justifies its specific name.

4. P. FERULACEA Suhr in J. G. Agardh, 1863, p. 980; P. B.-A., No. 1940; *P. breviarticulata* Harvey, 1853, p. 36, Pl. XVI. B, not of J. Ag. Rein, as *P. nigrescens* in part; Moseley, as *P. subtilissima;* Spanish Point, Harrington Sound, Jan., Gravelly Bay, Feb., April, Tucker's Town, Feb., Dec., Hervey. A rather common and generally distributed species. Harvey's figure represents the plant quite accurately, except as to the quadrangular section of the filaments, which was probably due to the use of dried material; the Bermuda material shows the usual circular section. Rhizoids are well developed on the lower, prostrate part, arising each from a pericentral cell, often one from each segment. Where the creeping filament is near to a firm substratum, the rhizoids are short and stout; where there is no such stratum near, the rhizoids may be much elongated, up to 3 mm. long, becoming very slender. In the actively growing tips, the segments may have a length of only one fifth their diameter; in older parts the segments may be slightly longer than their diameter; the usual length is about one half a diam. Leaves are abundant, branches being produced from their axils.

At Heron Bay we found a plant agreeing quite closely with *P. fracta* Harvey, 1853, p. 38, and with an authentic specimen in the Farlow herbarium; it seems to us, however, to be only an old and battered form of *P. ferulacea.* Authentic specimens of the latter, in the Farlow herbarium, confirm this view.

5. P. OPACA (Ag.) Zanardini, 1842, p. 165; P. B.-A., No. 1891; *Hutchinsia opaca* Agardh, 1824, p. 148. Kemp, as *P. fibrillosa;* Rein, as *P. nigrescens,* in part; On rocks, Heron Bay, Jan., March, Ely's Harbor, April, Hervey; in grotto, Tucker's Town, April, Fairyland, Dec., Collins. We have included under this name all the many-tubed Polysiphonias that we have found in Bermuda. Some specimens agree well with the European form, others, specially those from Fairyland, considerably resemble *P. simulans* Harvey, but we have not been able to draw any line between these and the more typical forms. Tetraspores were found in April. Branches arise in the axils of the leaves.

DIGENEA Agardh.

D. SIMPLEX (Wulfen) Agardh, 1822, p. 389; Harvey, 1853, p. 29, Pl. XIII. D; P. B.-A., No. 1939; *Conferva simplex* Wulfen, 1803, p. 7. Castle Harbor, Farlow; Gravelly Bay, Feb., Mangrove Bay, Feb., Harris Bay, April, Dec., Hervey; St. David's Island, April, Collins. Fairly common at various places, but plants usually small compared with ordinary forms of Florida and the Mediterranean.

Wrightiella Schmitz.

1. Main axes virgate, except in the older parts beset with short, subequal ramuli. 1. W. Blodgettii.
1. Branches of successive orders diminishing in size; ramuli of varying length. 2. W. Tumanowiczi.

1. W. Blodgettii (Harv.) Schmitz, 1893, p. 222; P. B.-A., No. 1942; *Alsidium Blodgettii* Harvey, 1853, p. 16, Pl. XV. B. Kemp, specimen in herb. as *Dasya mucronata,* also unnamed specimen; Shelly Bay, Feb., Harris Bay, Walsingham, April, Hervey; in pot-hole, Gravelly Bay, April, Bethel's Island, Dec., Collins; tetraspores in Jan. and April.

2. W. Tumanowiczi (Gatty) Schmitz, 1893, p. 222; P. B.-A., No. 2095. *Dasya Tumanowiczi* Gatty in Harvey, 1853, p. 64. Moseley; Buildings Bay, April, with cystocarps, Hervey. In this collecting a single plant was found, dense and bushy and over 7 dm. high; over 30 good mounted specimens were made from it, but it was throughout more slender than much smaller individuals of *W. Blodgettii.* In appearance the two species are quite different, the stout spinous branches of the latter are quite visible to the naked eye, and set all over the plant; in *W. Tumanowiczi* they are hardly visible without a lens. Technically, it is hard to find distinguishing characters; tetraspores and cystocarps are quite alike, and as suggested by Falkenberg, 1901, p. 559, they are certainly closely related.

Murrayella Schmitz.

M. periclados (Ag.) Schmitz, 1893, p. 227; P. B.-A., No. 2096; *Hutchinsia periclados* Agardh, 1828, p. 101; *Bostrychia Tuomeyi* Harvey, 1853, p. 58, Pl. XIV. E. Among *Bostrychia* species, on mangroves and rocks, Tucker's Town, Hungry Bay etc., Common as scattered individuals among other species, rarely pure or constituting the greater part of the growth.

Herposiphonia Nägeli.

1. Branches recurved. 3. H. pecten-veneris.
1. Branches straight. 2.
    2. Determinate branches about the same size as the axis. 1. H. secunda.
    2. Determinate branches about half the size of the axis. 2. H. tenella.

1. H. SECUNDA (Ag.) Falkenberg, 1901, p. 307, Pl. III, figs. 10–12; P. B.-A., No. 2041; *Hutchinsia secunda* Agardh, 1824, p. 149; *Polysiphonia pecten-veneris* Var. β Harvey, 1853, p. 46, Pl. XVI. D. On reef, Ely's Harbor, Aug., Collins. In this material the erect branches are often abortive, and the regularity of position of branches characteristic of the species is obscured.

2. H. TENELLA (Ag.) Nägeli, 1846, Pl. VII, fig. 2; P. B.-A., No. 1943; *Hutchinsia tenella* Agardh, 1828, p. 105. On rocks, corallines and other algae, Harrington Sound, Bailey's Bay, Gibbet Island, Jan., Smith's Bay, Feb., Nov., Harris Bay, April, Tucker's Town, Dec., Hervey.

3. H. PECTEN-VENERIS (Harv.) Falkenberg, 1901, p. 315; *Polysiphonia pecten-veneris* Harvey, 1853, p. 46, Pl. XVI. C. Among *Gelidiopsis*, Harris Bay, April, Hervey. A delicate and attractive species; the graceful recurving of the branches easily distinguishes it.

LOPHOSIPHONIA Falkenberg.

1. Pericentral cells 10–16. 3. L. obscura.
1. Pericentral cells 4. 2.
  2. Basal filament attached to substratum by filiform rhizoids, with or without disks. 1. L. bermudensis.
  2. Basal filaments penetrating the host by rhizoids much inflated below. 2. L. Saccorhiza.

1. **L. bermudensis** sp. nov.; Cellulis pericentralibus 4, interdum 5 aut 6; filamentis prostratis 100–110 μ diam., cellulis 1–2 diam. longis; filamentis erectis numerosis, ad 60 segmentis longis, 60–80 μ diam. a basi ad prope apicem; cellulis $1\frac{1}{2}$–2 diam. longis, interdum solummodo $\frac{1}{2}$ diam.; ramis plus minusve ramosis, aliquando densissime; ramis brevibus. Antheridiis conicocylindricis, 160–200 μ × 40–50 μ, ad apicibus ramorum aggregatis; cystocarpiis subglobosis, lateraliter sessilibus, vel ad pedicellum perbreve, circa 250 μ diam.; tetrasporangiis circa 80 μ diam., 2–5 in seriem rectilineam, in ramulis subincrassatis, saepe curvis. Plate III, figs. 18–21.

Pericentral cells 4, occasionally 5 or 6; prostrate filaments 100–110 μ diam., cells 1–2 diam. long; erect filaments numerous, up to 60 cells long, 60–80 μ diam. from base to near apex, cells $1\frac{1}{2}$–2 diam. long, occasionally only $\frac{1}{2}$ diam.; more or less branched, sometimes quite densely, branches short. Antheridia conical-cylindric, 160–200 × 40–50 μ, clustered at apices of branches; cystocarps subglobose, sessile or lateral on very short pedicels, about 250 μ diam.; tetrasporangia about 80 μ diam., 2–5 in a straight series, in somewhat swollen, often curved ramuli. Rhizoids filiform, varying in size but usually slender, attached to the substratum by a terminal disk. Type in Collins herbarium. Gravelly Bay, Feb., Hervey, Fairyland, Cave at Agar's Island, Aug., and dredged in 6 m., Collins. A rather delicate plant, usually on *Sargassum* or *Zonaria*, but also on limpet shells. The variation in number of pericentral cells is something exceptional in a plant of normally four. The increased number does not seem to be limited to any part of the plant, but may occur in horizontal or erect filaments, younger or older. It has some resemblance to *L. subadunca* (Kütz.) Falk., but that has uniformly six pericentral cells.

2. **L. Saccorhiza** sp. nov.; P. B.-A., No. 2042. Cellulis pericentralibus 4; filamentis prostratis 50–70 μ diam., segmentis 1–2 diam. longis; filamentis erectis numerosis, ad 2 mm. longis, 25–45 μ diam., ad basin abrupte, apicem versus longissime attenuatis, prope apicem folia bene evoluta sed fugacissima gerentibus; segmentis 2–3 diam. longis, ad apicem diametro brevioribus; filamento prostrato ad plantem hospitem rhizoideis numerosis affixo a parte inferiore filamenti ortis, primo cylindraceis vel ortu complanatis axis filamenti sensu, mox in saccos ovoideos expansis, ad 800 μ longis, 160 μ diam., inter utriculos plantae hospitis penetrantes. Tetrasporangiis uniseriatis in parte superiore filamenti erecti sitis, diametrum filamenti ad duplo superantibus; cystocarpiis subsphaericis, circa 100 μ diam., apicibus ramorum proximis, segmentis proxime inferioribus saepe ramulos breves solitarios vel paucos gerentibus. Antheridiis foliorum evolutione ortis, conico-ovoideis. Colore roseo; substantia molli. Plate II, figs. 13–14, Plate III, figs.15–17.

Pericentral cells 4; prostrate filaments 50–70 μ diam., segments 1–2 diam. long, erect filaments numerous, up to 2 mm. long, 25–45 μ diam., contracted abruptly at base, gradually towards apex, segments 2–3 diam. long, at growing tip shorter than the diam.; well developed but very fugacious leaves formed on the upper part; prostrate filaments attached to the host by numerous rhizoids issuing from the lower pericentral cells of the prostrate filament, one or more from a segment, at first cylindrical in section, or flattened in a line with the axis of the filament, below expanding into an ovoid sac, up to 800 μ long, 160 μ wide, penetrating between the utricles of the host. Tetrasporangia in a single series in the upper part of a filament, up to twice the diameter of the filament. Cystocarps subspherical, about 100 μ diam., near end of erect filament, one or more short branches issuing from the segments next below. Antheridia developed from leaves, conical-ovoid. Color rosy red; substance soft.

From the few 4-tubed species of *Lophosiphonia* this is distinguished by branching characters, but specially by the great development of the rhizoids, which show a remarkable adaptation to its habitat, the fronds of *Codium*. The rhizoids take the shape of utricles, of much the same shape and size as those of the host, but in reversed position. At first a relatively slender cell, cyclindrical, or occasionally flattened in a line with the axis of the filament, as soon as the rhizoid has penetrated between the stouter parts of the *Codium* utricles it expands, and wedges itself in tightly among the latter. As seen under the microscope, there is a striking contrast between the rosy color of one set of utricles, and the green of the other. Type in Collins herbarium, No. 7456, Gibbet Island, March, 1913, Hervey; also from Gibbet Island, Jan., Smith's Bay, March, Hervey; Tucker's Town, April, Cave near Ducking Stool, Hungry Bay, May, Collins.

3. L. OBSCURA (Ag.) Falkenberg, 1901, p. 500; P. B.-A., No. 1892; *Hutchinsia obscura* Agardh, 1828, p. 108; *Polysiphonia obscura* Harvey, 1846–51, Pl. CII. A. Moseley, as *Polysiphonia exilis;* Smith's Bay, Spanish Rock, Jan., Gibbet Island, March, Harrington Sound, Dec., Hervey; North and South Shores, April, May, July, Aug., Collins. Common everywhere on rocks between tide marks, and in caves, where in well sheltered places it reaches even above ordinary tides. It varies considerably in size and in luxuriance of branching, but is not likely to be mistaken for any other species. Young plants bear long hairs (leaves) in dense branching tufts.

BOSTRYCHIA Montagne.

1. Main axis ecorticate.	1. B. rivularis.
1. Main axis corticate.	2.
2. Long monosiphonous ramuli present.	2. B. tenella.
2. Only a few terminal segments monosiphonous.	3.
3. Tips of branches incurved; rather coarse.	4. B. Montagnei.
3. Branches straight; slender.	3. B. sertularia.

1. B. RIVULARIS Harvey, 1853, p. 57, Pl. XIV. D. Walsingham, April, Hervey. This species, the only one occurring as far north as New England, has been found only once in Bermuda, and then in a quite small form, not over 2 cm. high. It was sparingly scattered among *B. Montagnei.*

2. B. TENELLA (Vahl) J. G. Agardh, 1863, p. 869; P. B.-A., No. 1894; Alg. Amer.-Bor. Exsicc., No. 137, as *B. calamistrata; Fucus tenellus* Vahl, 1802, p. 45. Common on roofs and walls of caves, flat rocks, under mangroves, etc., at all seasons; tetraspores in Nov. The most common species of the genus; the species of *Bostrychia* usually grow intermixed with each other, and with *Caloglossa* and *Catenella;* it is exceptional to find any one species pure, while the combination of two or more, in varying proportions, is to be found everywhere in the stations noted for this species. *B. tenella* is quite variable, and the extreme forms seem quite distinct. Forma *tenuior* J. G. Agardh, 1863, p. 869; *B. calamistrata* Harvey, 1853, p. 56, Pl. XIV. C, and forma *densa* J. G. Agardh, 1863, p. 869; *Rhodomela calamistrata* Montagne, 1846, p. 36, Pl. IV, fig. 1, both occur, often in the same collecting, connected by intermediate forms.

3. B. SERTULARIA Montagne, 1859, p. 176; P. B.-A., No. 2094; Alg. Am.-Bor. Exsicc., No. 138. Grotto, Tucker's Town, Dec., Hervey; Gravelly Bay, April, Collins. The tetraspores of this species, of which there seems to have been no record, were found in material from the cave at Gravelly Bay, and are also in material distributed by Farlow, in Alg. Am.-Bor. Exsicc. A stichidium is formed in the limited branch of a main axis, usually occupying only a small part of its length, in the majority of cases below the middle, the unchanged branch extending both above and below the stichidium, bearing both above and below ramuli of normal construction; this appears to be an exception to the usual formation in this genus. *B. sertularia* has been considered by some as a synonym of *B. tenella,* e. g., De Toni, 1903, p. 1162, but the two seem quite distinct. *B. tenella* is a plant of softer substance, with long monosiphonous ramuli, and long-lanceolate or linear-lanceolate stichidia; *B. sertularia* is firmer, only a few of the extreme segments of a ramulus being monosiphonous; the branching is strictly distichous, and the stichidium occupies the middle part of the otherwise unchanged ramulus of the penultimate or ultimate order.

4. B. MONTAGNEI Harvey, 1853, p. 55, Pl. XIV. B; P. B.-A., No. 1893; Alg. Am.-Bor. Exsicc., No. 136. H. Kennedy, Feb. in Farlow herb.; July, Kemp, as *B. scorpioides;* Hungry Bay, April, May, Collins; Causeway, Nov., with cystocarps, Hervey. The largest and coarsest species. The cystocarps are large, depressed-globose, and terminal on rather long ultimate ramuli.

Dasya Agardh.

1. Divisions few, subsimple, ramelli very dense at tips. 1. D. ocellata.
1. More branched; ramelli less dense at tips. 2.
2. Ramelli all unbranched or forkings narrow. 3.
2. Ramelli divaricately or squarrosely branched, at least near base. 5.
3. Ramelli deciduous, leaving short, acute, spinous branches. 3. D. spinuligera.
3. Ramelli more persistent; no spinous branches. 4.
4. Ramelli very slender, short-celled, generally distributed on all but the oldest parts. 2. D. pedicellata.
4. Ramelli larger, longer-celled, in more or less distinct whorls. 4. D. punicea.
5. Ramelli stout near their base, diminishing at each forking, very slender at apex. 6.
5. Ramelli nearly uniform in size throughout. 5. D. arbuscula.
6. Ramelli forming a very dense coating, especially near tips of branches. 6. D. ramosissima.
6. Ramelli in minute, subcorymbose clusters, not denser near apices. 7. D. corymbifera.

1. D. ocellata (Grat.) Harvey in Hooker, 1833, p. 335; 1846–51, Pl. XL; *Ceramium ocellatum* Grateloup, 1807, p. 34. Cooper's Island, Feb., Farlow; on *Sargassum*, Gibbet Island, Jan., Gravelly Bay, Feb., Hervey; tetraspores in Jan.

2. D. pedicellata Agardh, 1824, p. 211; *D. elegans* Harvey, 1853, p. 60; Kützing, 1864, p. 21, Pl. LIX. Kemp, as *D. pediculata;* Merriman; Miss Peniston; Miss Wilkinson; Shelly Bay, April, Collins; Buildings Bay, March, Hervey. The common *Dasya* of the Atlantic coast from Cape Cod to Florida, but evidently not common here. Though the name *D. elegans* has been long familiar, it will have to be given up for *D. pedicellata,* the priority of which is unquestionable.

3. **D. spinuligera** sp. nov.; P. B.-A., No. 2188. Cellulis pericentralibus 5, corticatis, cortice glabro, continuo, cellularum minorum, elongatarum; ramis paucis, elongatis, ramulos breves, patentes, acutos, gerentibus; apice ramuli junioris fasciculum densum ramellorum ferente, adultioris nudo; ramellis densissimis, deciduis, monosiphoniis, dichotomis, rectis nec divaricatis, cellulis 2–3 diam. longis, superne 1 diam. modo, diametro ubique aequali; stichidiis conicis vel cylindro-conicis, prope basin fasciculi ramellorum ortis; tetrasporangiis 2–4 in verticillo; frondis substantia firma; colore rubro obscuro. Plate IV, figs. 24–25.

Pericentral cells 5, corticate, cortex smooth, even, of small elongate cells; with few elongate branches, bearing patent, acute ramuli, the younger with a dense fascicle of ramelli at the tip, the older naked; ramelli very dense, deciduous, monosiphonous, dichotomous, straight, not divaricate; cells 2–3 diam. long, above only 1 diam.; diameter the same throughout; stichidia conical or cyclindric-conical, arising near the base of a fascicle of ramuli; tetrasporangia 2–4 in a whorl. Substance of the frond firm; color dark red. Type in Collins herbarium, No. 7243; collected at Shelly Bay, May 4, 1912, Collins. When ramelli are abundant, this plant somewhat resembles *D. punicea,* but the ramelli show no tendency to a verticillate arrangement, and fall off more easily. The surface of the frond after the ramelli have fallen is smooth and even, not knotted and irregular as in *D. punicea;* the cells are small and regular, not large and irregular as in that species.

4. D. PUNICEA Meneghini in Zanardini, 1842, p. 171; 1865, Pl. LII. Dingle Bay, March, Hervey; Bethel's Island, Dec., Collins; both with tetraspores. In habit somewhat resembling *D. pedicellata,* but the ramelli are larger, of longer cells, and with a distinct tendency to issue in whorls.

5. D. ARBUSCULA (Dillw.) Agardh, 1828, p. 121; Harvey, 1846–51, Pl. CCXXIV; P. B.-A., No. 1944; *Conferva arbuscula* Dillwyn, 1809, Pl. G. Shelly Bay, Jan., Smith's Bay, March, Harris Bay, April, Hervey; Hungry Bay, April, in dense floating masses and attached to mangroves, Collins.

6. D. RAMOSISSIMA Harvey, 1853, p. 61; Kützing, 1864, Pl. LXIX, figs. d–e; P. B.-A., No. 1945. On vertical rock between tides, Pink Beach, Jan., Feb., Smith's Bay, March, Gibbet Island, Dec., Hervey. In habit not unlike *D. corymbifera,* but the divisions of the ramelli are incurved.

7. D. CORYMBIFERA J. G. Agardh, 1841, p. 31; *D. venusta* Harvey, 1846–51, Pl. CCXXV; *D. arbuscula* P. B.-A., No. 1097b, not 1097a; *D. arbuscula* forma *subarticulata* P. B.-A., No. 493. Washed ashore from deep water, Buildings Bay, Feb., Hervey; dredged in 4 m., Nov., Collins. Sometimes confused with *D. arbuscula* which it resembles in habit; both have a dense coating of divaricately branching ramelli, but in *D. corymbifera* the tips of the ramelli are much more slender than their bases.

HETEROSIPHONIA Montagne.

H. WURDEMANNI (Bailey) Falkenberg, 1901, p. 638, Pl. XVI, fig. 11; P. B.-A., No. 2097; *Dasya Wurdemanni* Bailey in Harvey, 1853, p. 64, Pl. XV. C. Cooper's Island, Feb., Farlow; Harrington Sound, Jan., March, Gibbet Island, Dec., Hervey; Hungry Bay, April, Cooper's Island, Aug., Little Agar's Island, Nov., Collins. On *Gelidium* and other algae, but most frequently on *Sargassum;* a careful search would probably discover it in any lot of old *Sargassum*, but it is seldom found in large quantity.

Family CERAMIACEAE.

Spermothamnion Areschoug.

1\. Cells 5–20 diam. long; tetraspores usually in corymbose clusters. 3. S. macromeres.
1\. Cells 2–7 diam. long; tetraspores solitary. 2.
  2. Filaments 15–20 μ diam. 1. S. investiens.
  2. Filaments 40–50 μ diam. 2. S. gorgoneum.

1\. S. investiens (Crouan) Vickers, 1905, p. 64; *Callithamnion investiens* Crouan in Mazé & Schramm, 1870–1877, p. 141. On *Galaxaura squalida*, Gravelly Bay, April, St. David's Island, April, Collins; Harris Bay, Dec., Hervey. The dimensions of the Bermuda plant agree with those given by Miss Vickers for the Barbados plant; Börgesen, 1909, p. 17, fig. 10, describes and figures var. *cidaricola* from the Danish West Indies; the dimensions are considerably larger than in the typical form, but the habit and the tetraspores are the same as in the Bermuda plant.

2\. S. gorgoneum (Mont.) Bornet in Vickers, 1905, p. 64; *Callithmanion gorgoneum* Montagne, 1857, p. 289. Common on fronds of species of *Codium*. Tetraspores with tripartite division were found in Bermuda material, borne on an upcurved pedicel.

3\. **S. macromeres** sp. nov.; P. B.-A., No. 2044. Filamentis prostratis circa 65 μ diam., cellulis 3–5 diam. longis, rhizoideis magnum discum terminalem ferentibus, affixis; filamentis erectis 5–8 mm. longis, basi circa 50 μ diam., sensim diminutis, in ramis ultimis circa 30 μ; cellulis 5–20 diam. longis, cylindricis vel leviter clavatis, cellulis ramiferis valide clavatis; ramificatione distante, apparenter dichotoma, axi ramoque subaequalibus, minime divergentibus; tetrasporangiis in ramo laterali evolutis, ramum vegetativum referente, vel in ramis brevibus oppositis; ramis tetrasporangiferis raro simplicibus, vulgo di- trichotome ad cellulam quamque repetite divisis, cellulis brevibus, clavatis; tetrasporangiis terminalibus, tripartitis, 50–55 μ diam., globosis vel paullo elongatis, membrana crassa; antheridio latere interiore rami evoluto, loco rami vegetativi, ovoideo-cylindrico, 125–130 × 50–60 μ; cystocarpio cellula brevi clavata suffulto, loco rami vegetativi evoluta.

Prostrate filaments about 65 μ diam., cells 3–5 diam. long, attached by rhizoids with a large terminal disk; erect filaments 5–8 mm. long, about 50 μ diam. at base, gradually diminishing to about 30 μ in ultimate divisions, cells 5–20 diam. long, cylindrical or somewhat clavate, branch-bearing cells strongly clavate; branching usually distant, apparently dichotomous, the axis and branch nearly equal in size and diverging very slightly; tetrasporangia produced on a short branch arising like a vegetative branch, or on two short branches opposite on the axis; tetrasporic branches rarely simple, usually di- or trichotomously divided, the divisions each of a short, clavate cell; tetraspores borne on the ultimate divisions, tripartite, 50–55 μ diam., globose or slightly elongate, with wide pellucid wall; antheridium on the inner side of a branch, occupying the place of a vegetative branch, ovoid-cylindrical, 125–150 × 50–60 μ; cystocarp borne on a short, clavate cell, taking the place of a vegetative branch. Type in Collins herbarium, Smith's Bay, Jan. 18, 1913, Hervey. Also at the same place, Feb., March, Nov., Dec., Hervey.

The extremely long cells in this species, 20 diameters long being not uncommon, distinguish it from other species of the genus. The erect filaments are usually very sparingly branched, though in the upper half there may sometimes be a branch from every cell; in other cases the erect filament branches only two or three times in its whole length; the branch is hardly distinguishable from the axis, either by size or direction. The tetrasporangium may be terminal on a relatively short cell, 2–3 diam. long, arising from the axis; or this cell may divide one to several times, in the latter case twenty to thirty tetrasporangia being borne at the apices of the divisions, forming a dense, corymb-like cluster. The antheridia appear sessile, as they take the place of normal branches on the inner side of a secondary axis, the unmodified cells of which are shorter than the normal, though not as short as in the tetrasporic clusters; occasionally both branches of a forking are transformed into antheridia. Cystocarps are formed in the same position as antheridia, but the lower cell of the transformed branch remains unchanged. Antheridia were plentiful in material collected in January, tetraspores at all seasons; cystocarps were found in January material only, scarce and somewhat immature. The prostrate filaments are affixed by numerous short, stout rhizoids with much expanded terminal disks; occasionally a more slender rhizoid is produced by the lowest cell of an erect filament. The plant grew on the top of sand-covered rocks, covered at high tide; the coral sand sifted in among the alga, forming a dense fibrous mass.

CERAMOTHAMNION Richards.

C. CODII Richards, 1901, p. 264, Pl. XXI; P. B.-A., No. 1899; Plate III, fig. 22; plate IV, fig. 23. Common on *Codium tomentosum* and other species of *Codium* all about the islands, at all times of the year, almost always in abundant fruit. It was once found on *Laurencia cervicornis*. A few notes can be added to the quite full description of Richards. He observed only a single ripe tetrasporangium at a node; we have found not uncommonly two, rarely three, in one instance four, of apparently equal age, side by side; branches occasionally occur independently of the polyspores; we have found organs quite agreeing with his figures of the latter, but also similar organs, larger, up to 160 μ diam., spherical, containing up to 45 spores, and in appearance quite indistinguishable from cystocarps of *Ceramium*.[17] Against the identification of these organs as cystocarps must be reckoned our failure to discover anything like procarps, and the question must be left open. The rhizoids offer some interesting peculiarities, doubtless due to adaptation to their position, between the closely-packed utricles of the host; at first terete, they soon become flattened, and often two or more unite laterally, in a membranous expansion, which may be as much as 10 cells wide. In one case three rhizoids from one individual united with two from another to form one membrane. The cross walls in these rhizoidal membranes are often much oblique, and the arrangement of the cells reminds one somewhat of that in the leaf of a moss. See Figures 22 and 23. The material from which this species was described was collected in Bermuda in 1898 and 1899; the only other record of its occurrence is at Barbados, Vickers, 1905, p. 65.

GRIFFITHSIA Agardh.

1.	Vegetative cells cylindrical throughout.	1. G. tenuis.
1.	Lower cells subcylindrical, upper ovoid.	2. G. Schousboei.
1.	All cells subspherical.	3. G. monilis.

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[17] Schiller, 1913, has made extensive observations on organs of this character in genera allied to *Ceramothamnion*, and he reports that in every case they were accompanied by tetraspores of normal character on the same individual. This is not the case with this species.

1. G. TENUIS Agardh, 1828, p. 131; P. B.-A., No. 1895; Plate VI, figs. 38–39; *G. thyrsigera* Askenasy, 1888, p. 36, Pl. IX, figs. 1 & 4; Vickers, 1905, p. 64; *Callithamnion tenue,* Harvey, 1858, p. 130. Inlet, above and below Flatts Bridge, Jan., Feb., March, April, Dec., Heron Bay, Jan., Hervey. Common at these stations in late winter and early spring; cystocarps, antheridia and tetraspores all produced from January to March. The similarity between *Griffithsia tenuis* Ag. and *Callithamnion thyrsigera* Thwaites has been noticed more than once. Harvey, 1858, p. 130, kept up the distinction with some doubt. Grunow, 1874, p. 8, considers the latter merely a robust form of the former. Harvey had compared the plant from Beesley's Point, New Jersey, with an authentic Mediterranean specimen; we have compared with a Beesley's Point specimen of the original collecting specimens from Atlantic City, N. J. (S. R. Morse), Nantucket (L. L. Dame), Falmouth, Massachusetts (Collins), and *G. thyrsigera,* Vickers, Algues de la Barbade, No. 182. All agree in essential details with each other, and with the figures and text of Askenasy. The Bermuda material seems to be more luxuriant, especially the tetrasporic; it is not uncommon to find 15 tetrasporangia in a whorl, five whorls of tetrasporangia, mature or nearly mature, and two whorls of immature, at once on an axis. Antheridia are borne on a pedicel of one to three cells; Askenasy reports one-celled pedicels only. The cystocarps were unknown until found on our Bermuda material; they are characteristic of *Griffithsia,* and the generic position of the species may now be regarded settled. Rhizoids were frequent on the older plants, of the usual form, unicellular, longer or shorter as required to reach the substratum, where an expanded disk was formed. They have thicker walls than the filament cells, and contain nearly as deeply colored chromatophores.

2. G. SCHOUSBOEI Montagne in Webb, 1839, p. 11, Pl. X. Washed ashore, St. George's, Feb., sand covered rock, Pink Bay, March, Hervey. Agrees with the European plant in vegetative characters, but in the absence of fruit the identification is only provisional.

3. G. MONILIS Harvey, 1855, p. 559; in Hooker & Harvey, 1855–1860, p. 332, Pl. CXCV. B. In cave, Gravelly Bay, Dec., Jan., March, on sand-covered rocks, Smith's Bay, March, Hervey; Bethel's Island, Dec., Collins. Tetraspores in Jan. *G. monilis* is an Australian species, and its occurrence here is of interest. Agardh calls attention to its similarity to *G. Schousboei,* but while what we take for that species occurs in Bermuda, it has most of the cells cylindrical, a few ovoid, while in *G. monilis* the cells are strictly globose, or a little elongated or depressed.

CALLITHAMNION Lyngbye.

1. Branching distichous, pinnate. 2.
1. Branching radial or dichotomous. 3.
  2. Little cortication, cells long, ultimate ramuli long, slender. 4. C. roseum.
  2. Much cortication, cells short, pinnae decompound, ultimate ramuli, short, stout. 5. C. Hookeri.
3. Branching alternate throughout. 1. C. byssoideum.
3. Branching at least in part dichotomous. 4.
  4. Ultimate divisions long, slender. 6. C. cordatum.
  4. Ultimate divisions shorter and stouter. 5.
5. Alternate branching usually confined to axis and branches of first order, otherwise dichotomous. 3. C. Halliae.
5. Only smaller divisions dichotomous; distance very short between forkings. 2. C. corymbosum.

1. C. BYSSOIDEUM Arnott var. JAMAICENSE Collins, 1901, p. 258; P. B.-A., No. 2045. Gravelly Bay, Jan., Feb., March, Oct., Hervey; April, Aug., Collins. Growing in dense patches, not over 3 cm. high, just below low water mark, in a small cave. In the water it shows a peculiar bluish iridescence, like the bloom on a plum.

2. C. CORYMBOSUM (Eng. Bot.) Lyngbye, 1819, p. 125, Pl. XXXVIII. C.; Harvey, 1846–51, Pl. CCLXXII; *Conferva corymbosa* Eng. Bot., 1811, Pl. MMCCCLII. Washed ashore, Cooper's Island, Feb., Farlow; on *Wrightiella Blodgettii*, Harris Bay, April, Collins. In both cases with abundant tetraspores.

3. C. HALLIAE Collins in P. B.-A., No. 698; 1906, p. 111; P. B.-A., No. 1896. Outlet of Harrington Sound, Jan., Feb., March., Hervey, large and handsome plants; tetraspores in Jan., no other fruit; Burchell's Cove, Feb., large rich purple patches on bottom in shallow water, Hervey; shore of Agar's Island, Dec., Collins.

4. C. ROSEUM (Roth) Harvey in Hooker, 1833, p. 341; Harvey, 1846–51, Pl. CCXXX; *Ceramium roseum* Roth, 1798, p. 46. On *Codium*, near Causeway, Feb., Hervey, with tetraspores. The plants are attached to the *Codium* by a dense mass of slender filaments with red protoplasts, penetrating deeply the tissue of the host. They are continuations of the descending growths from the bases of the branches, which cover the lower part of the axis, as a cortex.

5. C. HOOKERI (Dillw.) Agardh, 1828, p. 178; Harvey, 1846–51, Pl. CCLXXIX; P. B.-A., No. 2046; *Conferva Hookeri* Dillwyn, 1809, Pl. CVI. Kemp, as *C. spongiosum*. Pink Beach, Jan., Feb.,

March, Gravelly Bay, Feb., March, April, Hervey. At Pink Beach this plant grew buried in fine sand, on an exposed rock; at Gravelly Bay in the cave with *C. byssoideum* var. *jamaicense,* not as large nor as well fruiting as at Pink Beach. At that station it bore tetraspores along the upper edge of the ramuli, as figured by Harvey; antheridia in rounded tufts at the same points; cystocarps large, spherical to ovoid, on opposite sides of a branch; the three on separate individuals. Paraspores were often found at the ends of the ramuli, ovoid, of varying size, up to 50 × 35 μ including the rather thick wall. Tetraspores were occasionally found on the individuals producing the paraspores, but no other organ of fructification. We saw no seriate paraspores, such as are found in *Seirospora Griffithsiana* Harv., but sometimes two were side by side, touching each other, at the end of an ordinary cell. Kylin, 1907, p. 152, figures and describes paraspores of *C. Hookeri,* but of quite a different type; they take each the place of a tetrasporangium, dividing to produce an indefinite number of spores, "polyspores" of most authors. De Toni, 1903, p. 1317, describes *C. Hookeri* with tetraspores and cystocarps, and vegetative characters quite as above, and adds "Cautissime haec a *Seirospora? Gaillonii,* quacum characteribus plurimis congruit, dignoscatur." The latter species is described by him, p. 1352, by vegetative characters and tetraspores only. There is practically no distinction as regards these characters between the descriptions of the two species. The final note under *S. Gaillonii* is "Seirosporae et cystocarpia (sec. Crouan) presentia." De Toni includes under *Seirospora,* with or without a ?, a number of species which do not seem to us to belong to that genus, and without any statement of his reasons for so assigning them; among them *Callithamnion byssoideum,* with var. *jamaicense* and three other varieties.

C. CORDATUM Börgesen, 1909, p. 10, figs. 5–6; P. B.-A., No. 2189. Washed ashore, Buildings Bay, Feb., Hervey. Abundant, but entirely sterile, so that the determination must remain doubtful, although the vegetative characters agree with Börgesen's description and figures.

GYMNOTHAMNION J. G. Agardh.

Plumaria Schmitz, not Stackhouse. The genus *Plumaria* was founded by Stackhouse, 1809, p. 58, *P. pectinata* type, with synonym *Fucus plumosus* Linnaeus. C. A. Agardh, apparently not knowing of this publication, proposed, 1817, p. XIX, the genus *Ptilota,* founded on the same *Fucus plumosus* L.; Agardh's genus has been generally accepted, and many recent species have been included in it. Ruprecht, however, 1856, p. 335, calls attention to the priority of Stackhouse's name, and makes the combination *Plumaria asplenioides*, and also uses the *P. pectinata* of Stackhouse. Otto Kunze, 1891, p. 911, takes the same position, and makes new combinations for 16 species of Ptilota, some of which, however, are unnecessary, as the species had already been properly transferred to *Euptilota* Kütz. Schmitz, 1889, p. 450, retains *Ptilota* for most of the species, including Stackhouse's type for *Plumaria*, but revivies *Plumaria* for *Ptilota elegans*, Bonnemaison, a species unknown to Stackhouse; and in 1896, p. 7, transfers to *Plumaria*, *Ptilota Schousboei* Bornet in Bornet & Thuret, 1876, p. 34, *Callithamnion elegans* Schousboei in Agardh, 1828, p. 162. Under the international rules of nomenclature, and probably under any rule, the name *Plumaria* must be retained for Stackhouse's type, *P. plumosa* and its congeners; *Ptilota* founded on the same species, has no standing, and the only name we find available for the species placed under *Plumaria* by Schmitz is *Gymnothamnion* J. G. Agardh, 1892, p. 27, type *Callithamnion elegans* Schousboe. Accepting this in place of *Plumaria* Schmitz, not Stackhouse, it will include *Gymnothamnion elegans* (Schousboe) J. G. Agardh, 1892, p. 27; *Callithamnion elegans* Schousboe in Agardh, 1828, p. 162; Bornet & Thuret, 1876, p. 32, Pl. X; *Ptilota Schousboei* Bornet in Bornet & Thuret, 1876, p. 34; *Plumaria Schousboei* Schmitz, 1896, p. 7. **G. sericeum** (Harvey) comb. nov.; *Ptilota sericea* Harvey,[18] 1846–1851, Pl. CXCI; *P. elegans* Bonnemaison 1828, p. 70; *Plumaria elegans* Schmitz, 1889, p. 450. **G. Harveyi** (Hooker) comb. nov.; *Ptilota Harveyi* Hooker, 1845, p. 271; *Plumaria Harveyi* Schmitz, 1896, p. 7. **G. pellucidum** (Harvey) comb. nov.; *Ptilota pellucida* Harvey in Hooker & Harvey, 1853–1855, p. 257; *Plumaria pellucida* Schmitz, 1896, p. 7; also a new species, described below.

The taxonomy is somewhat complicated; of the five species credited to this genus, two were published in 1828, *Ptilota elegans* and *Callithamnion elegans;* in 1876 Bornet transferred the latter to *Ptilota*, but as the specific name *elegans* was preoccupied, changed it to *P. Schousboei*. In 1896 Schmitz transferred both to *Plumaria* with specific names unchanged, but in 1892 J. G. Agardh had used *Callithamnion elegans* as the type of his new genus *Gymnothamnion*, hence

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[18] *Fucus sericeus* Gmelin, 1768, p. 149, Pl. XV, fig. 3, from Kamtschatka, can hardly be a *Gymnothamnion*. See Ruprecht, 1856, p. 337.

in transferring to the latter the other species of Schmitz's *Plumaria*, a new specific name is needed for *Ptilota elegans*, and we have taken Harvey's name as the next in order.

G. bipinnatum sp. nov.; filamentis basalibus circa 20–25 μ diam., ramificatione opposita, cellulis diam. 4–5, raro 6–7 longis, membrana crassa, nodis subconstrictis; axibus erectis basi 20–25 μ diam. superne attenuatis, ad apicem circa 12 μ, cellulis cylindricis vel subclavatis, inferioribus circa 3 diam. longis, apicem prope 1–1½ diam.; ramis oppositis apice cellulae singulae exeuntibus, parallelis, angula 50°–60°, rectis vel leviter recurvatis, axi referentibus sed minoribus, raro 15 μ diam. superantibus; ramorum aliis simplicibus, aliis et pluribus ramulos secundatos latere superiore ferentibus; ramulis 1–2-cellularibus, perraro magis; circumscriptione frondis ovata vel lanceolata; cellulis terminalibus rotundatis. Filamentis prostratis ramulos rhizoideos descendentes ferentibus, axibus erectis oppositis, cellula terminali ad substratum disco affixa. Tetrasporangiis in ramis et ramulis terminalibus, sphaericis vel subovoideis, 30–35 μ diam., tripartitis. Plate IV, fig. 26.

Basal filaments about 20–25 μ diam., with opposite branching, cells 4–5 diam. long, rarely 6–7, wall thick, nodes somewhat constricted; erect axes of about the same size near the base as the prostrate filaments, diminishing to 12 μ at apex; cells about 3 diam. long at base, near apex 1–1½ diam., cylindrical or slightly clavate, each bearing at the upper end a pair of opposite branches, forming an angle of 50–60° with the axis, straight or slightly recurved, similar to the axis, but averaging smaller, seldom over 15 μ diam.; these branches either simple or more commonly bearing on the upper side, on part or all of the cells, a second series of branches, 1–2 cells long, rarely more, 8–10 μ diam.; outline of frond ovate or lanceolate; terminal cells all rounded. Basal filaments producing, opposite to the erect axes, rhizoids of one or many cells, the end cell forming a disk of attachment when it reaches the substratum. The end of a basal filament sometimes becoming erect and developing into a frond similar to the erect axes; the erect axis sometimes extending beyond the pinnation, and after an indefinite number of unbranched cells, developing a second series of branches; or the prolonged naked axis descending and forming a prostrate filament bearing erect axes and rhizoids. Tetrasporangia terminal on the branches of the first and second orders, spherical or slightly ovoid, 30–35 μ diam., tripartite. Cystocarps? Antheridia? On wall of cave, Gravelly Bay, April, Hervey, type in Collins herbarium; on *Wurdemannia*, Harrington

Sound, Jan., cave, Agar's Island, July, Aug., shore of Gibbet Island, Aug., cave, Ducking Stool, Dec., Collins. Tetraspores in April, Aug. and Dec.

Growing on walls and roofs of caves, or in smaller cavities in rocks, usually among other algae with a creeping base, such as *Rhodochorton* and *Spermothamnion.* We have found this quite a puzzling form, as there are three European species, in different genera, of similar size and habit, and with tetraspores similarly placed. Two of these, *Ptilothamnion pluma* Bornet in LeJolis, 1863, p. 118 and *Plumaria Schousboei* (Bornet) Schmitz, 1896, p. 7, while differing in cystocarps and antheridia, are almost identical otherwise, but a comparison of the plates, Bornet & Thuret, 1876, p. 32, Pl. X, and Bornet & Thuret, 1880, p. 179, Pl. XLVI, shows that the *Plumaria* has shorter cells throughout, and that the branches arise at the upper edge of the cells of the axis, while in the *Ptilothamnion* they are distinctly lower. The Bermuda plant agrees exactly with *Plumaria Schousboei* in form and proportions of cells, and place of insertion of branches; on that account we have placed it in the genus Gymnothamnion, recognizing, however, that when the sexual fruit is discovered, a different disposition may be necessary. The uniformly opposite character of the branching is quite noticeable; even in the prostrate filaments any other branching is rare and evidently abnormal, though in most species with opposite branching in the erect parts, the basal part is apt to vary from this. Moreover, every rhizoid that we have observed is opposite to an erect axis. Bornet and Thuret, describing *P. Schousboei,* say "ils adherent par des crampons semblables a ceux des Spermothamnion et des Polysiphonia"; but an examination of Pl. X, fig. 1, shows all the rhizoids opposite to erect axes, while this is not the case in *Spermothamnion flabellatum* shown in Pl. VIII, fig. 1. We are led to keep the Bermuda plant separate from *P. Schousboei* principally from the fact that all well developed fronds bear erect branches of a second order, in luxuriant individuals one such branch from every cell of a branch of the first order, always on the upper side of the latter. If these branches were in pairs, the distinction would be less important, and might mean merely a repetition of the normal branching in luxuriant individuals, but we have never seen an outgrowth from the under side of a branch of the first order. Curiously enough, this mode of branching is identical with that of *Antithamnion pteroton* (Schousb.) Bornet, 1892, p. 331, Pl. III, figs. 8–9, in regard to which the author says, "Cette élégante petite Algue ressemble beaucoup aux *Callithamnion pluma* et *elegans* mais elle est plus délicate, d'une couleur plus rose. Elle s'en distingue surtout, parce que ses pinnules, lorsqu'elles sont bien developpées, portent des pinnules de second ordre sur leur bord superieur et que les tétraspores sont divisés en croix." The tetraspores in the Bermuda plant are distinctly tripartite. As a secondary distinction we would note that a prostrate axis can become erect and an erect axis prolong itself and either develop a new branch system at some distance from the old, or be transformed into a prostrate axis.

The type specimen of the species is No. 7521 in the Collins herbarium; from the cave at Gravelly Bay, collected by Hervey in April, 1913.

ANTITHAMNION Nägeli.

A. CRUCIATUM (Ag.) Nägeli, 1847, p. 200; P. B.-A., No. 2191 *Callithamnion cruciatum* Agardh, 1827, p. 637; Harvey, 1846–51, Pl. CLXIV. Abundant and luxuriant on an old wreck, Castle Harbor, St. George's, April, on rock, Spanish Point, March, May, small form in cave, Gravelly Bay, Dec., Hervey.

Var. **radicans** (J. Ag.) comb. nov.;[19] P. B.-A., No. 2047; *A. cruciatum F. radicans* Hauck, 1885, p. 71; *Callithamnion cruciatum* var. *radicans* J. G. Agardh, 1841, p. 44. Creeping on perpendicular or overhanging rocks between tides, North Shore opposite Gibbet Island, Aug., Collins; Dec., Hervey. The main axis is prostrate, about 40 μ diam., the cells cylindrical, 2–5 diam. long; near the upper end of each cell is a pair of opposite branches; whorled branches were not seen. Successive pairs of branches are not in the same plane, but are more or less exactly decussate. The lower cell of each branch is short, no longer than broad, more or less rounded; the following cells are 2–4 diam. long, growing shorter upward; the diam. at the base of the branch, 20–25 μ. The short basal cell often bears a long, simple, rhizoidal branch, the cells up to 10 diam. long, about 15 μ diam., of paler color than cells elsewhere in the plant; the terminal cell of this rhizoid may form a discoid expansion, attaching itself to the substratum. All normal branches, whether issuing from the upper or the lower surface of the main filament, turn upwards; their branching is always alternate, a ramulus from each cell, all nearly or quite

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[19] This combination occurs in Collins, 1900, p. 48, attributed by error to J. G. Agardh. No synonymy being given, it can hardly be considered a publication. The difference from the typical *A. cruciatum* seems too great to consider it as a form, as was done by Hauck.

in the same plane; these branches are of 2 or 3 orders, the ultimate about 12 μ diam., the cells about 2 diam. long, nodes more or less constricted; the end cell is distinctly acuminate or subulate. "Drusenzellen" are abundant, borne usually on the inner side of the lower cell of an ultimate branch, in the same way as a tetrasporangium; they are spherical, about 20 μ diam., or slightly elongate, 18 × 24 μ, with rather thin wall, strongly refringent, yellowish or pale aeruginous contents. Occasionally the cells of a branch or of a system of branches assume a spherical form, as if becoming seirospores, but the contents do not seem to become darker or denser; the end cell rounds the lower end, but remains pointed above. No fructification was observed. The plant is very small, the axis seldom over 1 cm. long, the branches hardly 1 mm.; it is possible that this is not the variety *radicans* of J. G. Agardh, of which we have not seen type specimens. Descriptions as far as we know have been short and imperfect, which has led us to describe the Bermuda plant in rather full detail.

CROUANIA J. G. Agardh.

C. ATTENUATA (Bonnem.) J. G. Agardh, 1842, p. 83; Harvey, 1853, p. 226, Pl. XXXI. D; P. B.-A., No. 2048; *Batrachospermum attenuatum* Bonnemaison in Agardh, 1824, p. 51, as synonym under *Mesogloia attenuata.* Very young plants on *Caulerpa,* Harris Bay, Jan., Nov., plants up to 1 dm. high, washed ashore, Buildings Bay, Feb., March, Hervey.

SPYRIDIA Harvey.

1. Branching mostly distichous. 3. S. complanata.
1. Branching radial. 2.
  2. Recurved prickles at ends of ramuli. 2. S. aculeata.
  2. No recurved prickles. 1. S. filamentosa.

1. S. FILAMENTOSA (Wulf.) Harvey in Hooker, 1833, p. 337; Harvey, 1846–51, Pl. XLVI; P. B.-A., No. 1897; *Fucus filamentosus* Wulfen, 1803, p. 64. Kemp; Tucker's Town, Feb., Harrington Sound, Jan., Feb., Nov., Hervey. Abundant, probably everywhere about the islands. Occasionally handsome plants can be found, but they are mostly matted and unattractive. The three species of *Spyridia* are much alike in habit; but generally easily distinguished on microscopic examination.

2. S. ACULEATA (Schimper) Kützing, 1843, p. 327; 1862, Pl. LI;

Ceramium aculeatum Schimper in Decaisne, 1841, p. 179. Kemp; Merriman; Harris Bay, Nov., Harrington Sound, Aug., Hervey. Tetraspores in Nov.

Var. Berkeleyana (Mont.) J. G. Agardh, 1876, p. 272; *S. Berkeleyana* Montagne, 1846, p. 141, Pl. XV, fig. 8. Dense tufts on exposed flat rocks at low water, Gravelly Bay, April, Collins, with tetraspores. In this variety the recurved prickles characteristic of the species are usually present, but may sometimes be lacking, in which case it approaches *S. filamentosa.*

Var. hypneoides J. G. Agardh, 1876, p. 272; P. B.-A., No. 1946. Castle Harbor, near Walsingham House, April, Harris Bay, March, April, Hervey; tetraspores in collections of both months. The hooked tips of some of the branches, similar to those of *Hypnea musciformis,* characterize this form. The specimen marked *C. aculeata* in the Kemp herbarium belongs to this variety.

3. S. complanata J. G. Agardh, 1851, p. 343; 1876, p. 271; P. B.-A., No. 1947. Harris Bay, Jan., Feb., April, Pink Bay, March, Hervey; Hungry Bay, Nov., Elbow Bay, Dec., Collins. Growing in dense tufts on flat rocks near low water.

Ceramium Agardh.

1. Cortication continuous.	2.
1. Cortication at nodes only.	3.
2. Corticating cells in longitudinal series.	5. C. clavulatum.
2. Corticating cells not in series.	4. C. nitens.
3. Main axis creeping, attached by rhizoids.	4.
3. Main axis erect.	1. C. tenuissimum.
4. Tetraspores cruciate.	2. C. cruciatum.
4. Tetraspores tripartite.	3. C. transversale.

1. C. tenuissimum (Lyng.) J. G. Agardh, 1851, p. 120; 1876, p. 94; P. B.-A., No. 1898. *C. diaphanum* var. *tenuissimum* Lyngbye, 1819, p. 120, Pl. XXXVII. B, fig. 4; *C. nodosum* Harvey, 1846–51, Pl. XC. Miss Peniston; Harrington Sound, March, Wadsworth; Harris Bay, Jan., Heron Bay, March, Harrington Sound, April, Hervey; Hungry Bay, May, Fairyland, Dec., floating, Collins. This is the plant that passes by this name on the New England coast, and also Miss Vickers Algues de la Barbade, No. 199; it does not have the reniform cells considered characteristic of *C. tenuissimum* by Petersen, 1908, p. 54, Pl. III; but in the present uncertainty of specific limitations in *Ceramium,* it had better retain the present name. No fruit of any kind has been observed by us.

Var. PATENTISSIMUM (Harv.) Farlow, 1881, p. 138; *C. arachnoideum* var. *patentissimum* Harvey, 1853, p. 217, Pl. XXXIII. B. Heron Bay, Jan., Hervey. The frequent wide forkings give a habit quite different from the typical form, but there is agreement in essentials.

Var. ARACHNOIDEUM (Ag.) J. G. Agardh, 1851, p. 117; 1876, p. 94; P. B.-A., No. 2098. *C. arachnoideum* Harvey, 1853, p. 217; *C. diaphanum* var. *arachnoideum* Agardh, 1824, p. 134. On *Cymodocca* and various algae, Grasmere, Feb., Harvey. A very slender and delicate form, but otherwise like the typical form.

Var. PYGMAEUM (Kütz.) Hauck, 1888, p. 460; P. B.-A., No. 2193; *Hormoceras pygmaeum* Kützing, 1862, p. 23, Pl. LXXV. On *Codium decorticatum,* Cooper's Island, Aug., Collins. With tetraspores.

2. **C. cruciatum** sp. nov.; P. B.-A., No. 2192. Minuta, ad algas alias repens; filamentis prostratis circa 200 μ diam., cylindricis vel ad nodos leviter constrictis, rhizoidis unicellularibus incoloratis affixis; filamentis erectis passim ad nodos evolutis; apice filamenti prostrati assurgente, in filamentum erectum transformato; cellulis inferne circa 3 diam. longis, superne brevioribus, prope apicem diametro brevioribus; ramulis penultimis 80–100 μ diam.; ramis repetite dichotomis, cellulis cylindricis vel plus minusve ad nodos constrictis; apicibus forcipatis; corticatione cellulis sensu filamenti elongatis constante, irregulariter positis, zonam arctam formante margine inaequali. Protoplasma cellularum inferiorum subcylindricum, superiorum subsphaericum, fasciis tenuissimis longitudinalibus notata, raro anastomosantibus, nec longitudinem cellulae aequantibus, plerumque spatio latitudinem fasciae aequali separatis. Tetrasporangiis ovoideis, circa 50 × 35 μ, membrana 6 μ crassa non inclusa, 1–4 ad nodum, cruciatis, modo regulariter, modo decussate; aut singulis ad nodum, seriem externalem longitudinalem formantibus, aut pluribus nodum circumdantibus; dimidio sporangii extra corticem emergente. Plate IV, figs. 27–28.

Minute, creeping on other algae; prostrate filaments of about 200 μ diam., cylindrical or slightly constricted at nodes, attached by unicellular, colorless rhizoids, issuing from the nodes; erect filaments occasionally arising at nodes; apex of prostrate filament becoming erect and assuming the character of an erect filament; cells about 3 diam. long below, diminishing towards the apex, to less than one diam.; penultimate branches 80–100 μ diam.; branches repeatedly forking, cells cylindrical or with nodes more or less constricted; apices forcipate; cortication consisting of cells elongate in the direction of the filament, in no definite order, band narrow, edge uneven.

Protoplast subcylindrical in the lower cells, subspherical in the upper, marked with a pattern of delicate, longitudinal bands, seldom anastomosing or extending the length of the cell, usually separated by spaces of about their own width. Tetrasporangia ovoid, about 50 × 35 μ, excluding wall about 6 μ thick, 1–4 at a node, cruciate, sometimes regularly, sometimes decussately; when singly at a node they form an external longitudinal series; when more than one, they are irregularly placed about the node; about half of the sporangium projecting beyond the cortication. On *Padina variegata,* Gibbet Island, Jan. 16, 1913, Hervey, type in Collins herbarium, No. 7418a; also on *Galaxaura,* Gravelly Bay, April, on various algae, Hamilton Harbor, Dec., Collins.

In habit like the following species, *C. transversale,* but a larger plant, and distinct by the division and position of the tetraspores, and the character of the cortication. Only tripartite tetraspores have been recorded for any of the numerous species of *Ceramium,* but as other characters agree, it does not seem desirable to remove it from the genus.

3. **C. transversale** sp. nov.; P. B.-A., No. 2049. Minuta, ad alias algas saxaque repens; filamento prostrato 60–90 μ diam., cellulis sesqui-8 diam. longis, cylindricis vel ad nodos leviter contractis, rhizoidis unicellularibus, incoloratis affixis, ad nodos singulis pluribusve ortis; filamentis erectis passim ad nodos evolutis; filamenti prostrati apice assurgente, in filamentum erectum transformato; ramulis penultimis circa 60 μ diam.; filamentorum erectorum cellulis ad 2 diam. longis, non amplius; prope apicem diametrum non aequantibus; filamentis erectis repetite dichotomis; cellulis inferioribus cylindricis, superioribus adparenter brevissime clavatis, causa corticationis ad apicem; corticatione a parte corticata distinctissima, super seriem cellularum transverse elongatarum series 2 vel 3 cellularum rotundo-angulatarum irregulariter positarum gerente. Protoplasma uniformiter granulosum vel striis tenuibus, parallelis, longitudinalibus notatum per totam longitudinem cellulae; in cellulis inferioribus cylindrica, in superioribus subsphaerica. Cystocarpio evoluto ad apicem segmenti 2–5-cellularis, cellulis supra incrassatis, cellula summa cellulam imam duplo plusve majore, nonnullos ramos paucicellulares involucrales, cystocarpios 1–2 includentes gerente; cystocarpiis adparenter terminalibus, atque axi plerumque ultra cystocarpios et involucrem protenso, ex cellulas paucas constante, cellula basali 2–3 diam. longa, ceteris, ut cellulis involucri, vix 1 diam. Tetrasporangiis tripartitis, ad 60 μ diam., membrana 8 μ crassa non

inclusa; uno, raro duobus ad nodum, corticatione fere liberis, secundum ramum longitudinaliter seriatis. Plate V, figs. 29–31.

Minute, creeping over other algae or rocks; prostrate filaments 60–90 μ diam., cells 1½–8 diam. long, cylindrical or slightly constricted at nodes, attached by colorless, unicellular rhizoids issuing one or more at a node; an erect branch occasionally issuing at a node; apex of prostrate filament becoming erect and similar to an erect branch; penultimate branches about 60 μ diam.; cells in erect part not over 2 diam. long, near the apex less than one diam.; repeatedly forking; lower cells cylindrical, upper apparently very shortly clavate by the growth of cortication at the upper end; cortication sharply marked off from uncorticated portion, the lower portion of each band showing a series of transversely elongate cells passing around the central cell; the upper part of 2–3 series of irregularly placed roundish-angular cells. Protoplast uniformly granular, or with slender, parallel, longitudinal striations the whole length of the cell; the protoplast cylindrical in the lower cells, subspherical in the upper. Cystocarp borne at the end of a segment of 2–5 cells, which increase in size upward, the upper cell being twice the diam. of the lower or even more; on this are borne several wide-spread, few-celled involucral branches with one or two cystocarps between them, the cystocarps appearing terminal, but with usually an axis extended beyond them and the involucre, of few cells, the basal cell 2–3 diam. long, the others, as all the cells in the involucre, hardly 1 diam. long. Tetrasporangia tripartite, up to 60 μ diam. not including the wall 8 μ thick; one, occasionally two at a node, in longitudinal series, nearly free from the cortication.

On *Galaxaura*, Spanish Rock, April 10, 1914, Hervey, type in Collins herbarium, No. 8107. Also occurring on *Zonaria variegata*, Harrington Sound, May, on *Padina variegata*, Agar's Island, Nov., on *Thalassia*, Fairyland, Dec., Collins; on *Ascothamnion*, Tucker's Town, July, Howe.

The peculiar form of cortication, from which we have taken the specific name, does not seem to occur in any other species. *C. miniatum* Suhr, resembling it in some respects, has distichous branching, and small tetrasporangia sessile on both sides of the branches. Specially characteristic of *C. transversale* are the serrate outlines near the apices, due to the sharp limitation of the cortical growth there, and the tetraspores unusually large in proportion to the size of the frond. When two tetrasporangia are formed at a node, they are set side by side, the line made by the series of single sporangia passing between them. The cystocarps appear as if terminal, as the short prolongation of the axis is liable to be mistaken for an involucral branch. In younger parts the cells of the basal layer are seldom over 2 diam. long; in older parts these cells may be up to 8 diam.; the corticating band does not increase in width, but is as narrow and sharply limited in the longest cells as in the others.

4. C. NITENS (Ag.) J. G. Agardh, 1851, p. 130; P. B.-A., No. 1949; *C. rubrum* var. *nitens* Agardh, 1824, p. 136. Harrington Sound, Jan., Dec., Hervey; Inlet, Aug., Agar's Island, Fairyland, Nov., Dec., and dredged down to 18 m., Dec., Collins.

5. C. CLAVULATUM Agardh in Kunth, 1822, p. 2; P. B.-A., No. 1948; *Centroceras clavulatum* Harvey, 1853, p. 211, Pl. XXXIII. C. Rein; Kemp; Wadsworth, Harrington Sound, No. 18. As this plant is abundant practically everywhere, we give no detail of stations of our own collecting. It is very variable, and many species have been proposed in the past, only to be found unworkable; it may be that some time a successful segregation will be made, but it can hardly be done with habit characters, which are very inconstant. Tetraspores were found in Nov. & Dec., but no other fructification has been observed by us. In the Kemp herbarium are specimens marked respectively *C. rubrum* and *C. fastigiatum*, which belong to this species. *C. cryptacanthum* reported by Moseley is a synonym.

RHODOCHORTON Nägeli.

1. Saxicolous; prostrate filaments bearing erect filaments. 1. R. speluncarum.
1. Endozoic; in tubes of bryozoans etc. 2. R. membranaceum.

1. **R. speluncarum** sp. nov. Filamentis prostratis 30–40 μ diam., membrana 4–5 μ crassa, cellulis 2–3 diam. longis; rhizoideis brevibus affixis, a parte media cellulae exeuntibus, in discum majorem minoremve desinentibus. Filamentis erectis cylindricis vel minime diminutis apicem versus, e superficie superiore filamenti prostrati exeuntibus, prope mediam partem cellulae, saepius rhizoideis oppositis, 24–30 μ diam., membrana 2–3 μ crassa, cellula inferiore 2–2½ diam. longa, cellulis ceteris 3–4 diam. longis, cellula terminali rotundata; filamentis erectis aut simplicibus aut ramis paucis alternatis vel secundis prope apicem munitis. Fructificatio ignota.

Prostrate filaments 30–40 μ diam., wall 4–5 μ thick, cells 2–3 diam. long, attached by short rhizoidal branches issuing from the middle part of a cell, ending below in a larger or smaller disk. Erect filaments cylindrical or very slightly tapering, issuing from the upper surface of the prostrate filament, near the middle of a cell, usually opposite a rhizoid, 24–30 μ diam., walls 2–3 μ thick, lower cell 2–2½ diam. long, other cells 3–4 diam. long, terminal cell rounded; erect filaments sometimes unbranched, sometimes with a few alternate or secund branches near the apex. Fructification unknown. On rocks between tides, cave, Agar's Island, Aug., Nov., Collins.

This plant forms a plush on flat rocks a little above low water mark, as does *R. Rothii* (Turton) Näg. in similar stations on the shores of the North Atlantic, and its manner of branching resembles that of the latter species but its dimensions are about double. We have examined many specimens of *R. Rothii*, from both coasts of North America as well as from Europe, and find very little variation in size among them. In *R. speluncarum* the chromatophores are numerous small granules, usually densely packed, occasionally looser and showing something like a network. Type in Collins herbarium, No. 8401, Nov. 23, 1915.

2. **R. membranaceum** (Magnus) Hauck, 1885, p. 69; *Callithamnion membranaceum* Magnus, 1874, p. 67, Pl. II, figs. 7–15. In bryozoans, Bethel's Island, Dec., Collins.

Family GRATELOUPIACEAE.

Halymenia Agardh.

1.	Frond many times dichotomous, digitate, cylindrical.	4. H. Agardhii.
1.	Frond plane, simple or proliferous.	2.
2.	Thin, not gelatinous.	1. H. bermudensis.
2.	Thicker, gelatinous.	3.
3.	Large echinate cells in subcortex.	2. H. echinophysa.
3.	Few or no echinate cells in subcortex.	3. H. pseudofloresia.

1. **H. bermudensis** Collins & Howe, 1916, p. 169; P. B.-A., No. 2050; Plate V, fig. 34, plate VI, fig. 37. In shallow water in clefts of rocks and among roots of mangroves, often in loose, unattached masses. Kemp. Aug., as *Rhodymenia palmata;* Walsingham, Feb., Farlow; Oct., Miss Peniston; near Hamilton, June, Tucker's Town, July, Howe; Green Bay, March, Wadsworth; Harrington Sound, Jan., Tucker's Town, Feb., Dec., Dingle Bay, March, Grasmere,

March, Old Ferry, April, Hervey; Castle Harbor, April, Tucker's Town, May, Collins.

2. H. ECHINOPHYSA Collins & Howe, 1916, p. 180. Dredged in 31 fathoms off Bermuda by members of the Challenger Expedition, 1873, and reported, Moseley, 1884, p. 117, as *Kallymenia reniformis* J. Ag. Type and only specimen in herbarium of Royal Botanic Garden, Kew, England.

3. H. PSEUDOFLORESIA Collins & Howe, 1916, p. 177; P. B.-A., No. 2099; Plate V, fig. 35, plate VI, fig. 36. Faxon; Feb., Farlow; Green Bay, Feb., Shark's Hole, March, Wadsworth; Castle Harbor near Tucker's Town, April, Collins; Walsingham, Jan., Hervey; Aug., H. A. Cross. At Castle Harbor in narrow shaded clefts of rocks, well below low water mark; at Walsingham loose and unattached, the older parts darker and coarser than the young growth.

The three preceding species show some superficial resemblance in habit, but we consider them distinct. Full details will be found in Collins & Howe, 1916.

4. H. AGARDHII De Toni, 1905, p. 1543; *H. decipiens* of American authors, not of J. Ag. Oct., Miss Peniston; W. Faxon; Castle Harbor, in 2–3 meters water, July, Howe; at low water mark, under overhanging rocks, shore near Gibbet Island, Aug., Collins.

CRYPTONEMIA J. G. Agardh.

1. Midrib distinct.	2. C. luxurians.
1. No midrib.	1. C. crenulata.

1. C. CRENULATA J. G. Agardh, 1847, p. 11; Kützing, 1869, Pl. XXXI; P. B.-A., No. 2100. Kemp; Gravelly Bay, April, Collins, Dec., Hervey. In somewhat matted masses in the cave at this station, on a sand-covered rock; a smaller form than that commonly found in Florida.

2. C. LUXURIANS (Ag.) J. G. Agardh, 1851, p. 228; *Sphaerococcus Lactuca* var. *luxurians* Agardh, 1822, p. 232; *Euhymenia luxurians* Kützing, 1869, Pl. XXXII. Kemp, as *Botryoglossum platycarpum;* Cooper's Island, Miss Wilkinson; Buildings Bay, Jan., Hervey. Apparently not common.

FAMILY DUMONTIACEAE.

DUDRESNAYA Bonnemaison.

1. Peripheral filaments cylindrical or nearly so.	1. D. crassa.
1. Peripheral filaments distinctly moniliform.	2.
2. Auxiliary cell terminating the auxiliary branch.	3. D. caribaea.
2. Auxiliary cell in middle of auxiliary branch.	2. D. bermudensis.

1. D. CRASSA Howe, 1905, p. 572, Pl. XXVIII, XXIX, figs. 12–26; P. B.-A., Nos. 1900, 2196. Castle Harbor, Spanish Point, July, Howe; Castle Harbor, A. E. Wight in Farlow herb.; Salt Kettle, Feb., Buildings Bay, March, Spanish Point, March, Hervey; Shelly Bay, April, Collins. The plants from Buildings Bay, Spanish Point and Shelly Bay were washed ashore; at Salt Kettle, Paget, it grew just below low water mark; at the type station in Castle Harbor it grew at 3 m. depth at low water. It varies much in habit, from the form with short, stout branches, figured by Howe, to forms with slender, acute branches; from generally rounded outline to loosely pyramidal; from forms so dense that when spread out on paper they cover it continuously, without interstices between the branches, to quite open specimens, all branches distinct. The largest plant noted was about 25 cm. high and 15 cm. broad. Howe had only cystocarpic plants when describing the species, but we have found antheridia equally abundant, always on separate individuals. The antheridia are formed near the ends of the peripheral filaments, which here bear short, erect lateral branches, usually covered with minute densely branched ramuli of a few cells each, the terminal cell becoming the antheridium. According to the length of the axis and the amount of branching in the ramulus, the antheridia may be cylindrical, conical or ovoid. Sometimes the antheridia are so abundant on the peripheral filaments as to form a dense continuous mass, through which it is difficult to see the filaments, except the tips, which project beyond the antheridia. Both antheridial and cystocarpic plants were distributed as P. B.-A., No. 1900. Some forms are habitually not unlike *D. caribaea* and *D. bermudensis,* but are easily distinguished microscopically by the character of the peripheral filaments. It is often overgrown with *Acrochaetium corymbiferum,* and when both have abundant antheridia, it may be perplexing to one unfamiliar with the species.

2. D. BERMUDENSIS Setchell, 1912, p. 244, Pl. XXVII, fig. 8; P. B.-A., No. 2195. Cooper's Island, Feb., Farlow, washed ashore in abundance; St. George's, washed ashore, March, Hervey.

3. D. caribaea (J. Ag.) Setchell, 1912, p. 241, Pl. XXVI; *Calosiphonia caribaea* J. G. Agardh, 1899, p. 84. Cooper's Island, Feb., Farlow; washed ashore in abundance. This species and the preceding are very much alike in habit, and can be distinguished with certainty only by microscopic examination of plants in fruit.

These three species of *Dudresnaya* illustrate the possibilities of algae collecting. *D. bermudensis* is known only from Bermuda, from the material collected by Farlow on a single day in 1881 at Cooper's Island, and from a single collecting at St. George's in 1916 by Hervey; the Bermudian material of *D. caribaea* was all collected on the same day in 1881, and only one other station, Tortugas, Florida, is known; *Calosiphonia verticillifera* was collected at the same day and place, and is known elsewhere from the Tortugas station only. Material of all three species was abundant that day, but there is no record of any one of the species since, except the single collecting of *D. bermudensis,* though we have both been on the watch for them for the past five years, and have made visits to Cooper's Island at the same time of year as Farlow's collecting and at other times, to search for them. On the other hand we have found *D. crassa,* not known until 1905, in abundance at distant stations.

Family NEMASTOMACEAE.

Calosiphonia Crouan.

C. verticillifera (J. Ag.) Setchell, 1912, p. 247, Pl. XXVIII; *Helminthiopsis verticillifera* J. G. Agardh, 1899, p. 98. Cooper's Island, Feb., Farlow. As noted under *Dudresnaya,* this is one of the three species of handsome red fleshy algae, found in abundance on the same day in 1881, at Cooper's Island, and not observed since. In habit it is not unlike *Dudresnaya,* but is distinguished on microscopic examination by the shorter and stouter peripheral branches, forming a definite cortical layer.

Platoma Schmitz.

P. cyclocolpa (Mont.) Schmitz, 1889, p. 453; *Halymenia cyclocolpa* Montagne, 1840, p. 163; 1846, p. 116, Pl. XI, fig. b; *Nemastoma cervicornis* J. G. Agardh, 1879, Pl. IV, figs. 1–4. Cooper's

Island, Feb., Farlow, washed ashore; Castle Harbor, Gravelly Bay, April, Collins; Gravelly Bay, Dec., Hervey. Two large plants were collected in a narrow "chasm" in the rocky shore between Tucker's Town and Walsingham House, growing in company with *Halymenia bermudensis,* but while the latter grew plentifully at low water mark, the *Platoma* began about 5 dm. below, and seemed to extend down. Farlow's plants and ours from the cave at Gravelly Bay are smaller and of firmer substance; the Castle Harbor plants larger and looser, probably on account of being more developed.

Genus incertae sedis.

PORPHYRIDIUM Nägeli.

P. CRUENTUM (Eng. Bot.) Nägeli, 1849, pp. 71 & 139, Pl. IV. H; *Tremella cruenta* Eng., Bot., 1807, Pl. 1800. Roadside, Jan., Farlow. Forms a bright red film on the ground; is widely distributed and in northern countries is common in hothouses. It has been placed by different authors among green, blue-green and red algae respectively, but the latest investigations incline to the last. See Brand, 1908, p. 413.

SUMMARY.

Class.	Genera.	Species, marine.	Species, fresh water.
Myxophyceae	43	48	40
Chlorophyceae	56	95	28
Phaeophyceae	24	56	
Rhodophyceae	62	143	
Total	185	342	68
Total species		410	

LIST OF WORKS TO WHICH REFERENCE IS MADE.

Agardh, C. A.

- **1820.** Species Algarum rite cognitae, Vol. I, pars prior.[20] Lund.
- **1822.** Species Algarum rite cognitae, Vol. I, pars posterior. Lund.
- **1824.** Systema Algarum. Lund.
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- **1828–1835.** Icones Algarum Europearum. Leipzig.

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- **1854.** Nya algformer. Ofv. Kongl. Vet-Akad. Forh. Stockholm, Vol. XI, p. 107.
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[20] Though really only one edition was published of the Species Algarum of C. A. Agardh, copies are found with title pages of varying dates. As to actual dates of publication, see O. Nordstedt, The date of C. Agardh's Species Algarum, Bot. Notiser, 1914, p. 144.

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EXPLANATION OF PLATES.

PLATE 1.

Oedogonium consociatum Collins & Hervey.

Figure 1. Large cluster of young filaments. 255 × 1.
Figure 2. Smaller cluster of same. 255 × 1.
Figure 3. Single filament with attached basal cell. 550 × 1.
Figure 4. Filament with oogonium (immature). 550 × 1.

Chaetomorpha minima Collins & Hervey.

Figure 5. Filament of two cells. 800 × 1.
Figure 6. Filament of five cells. 550 × 1.
Figure 7. Filament of five emptied cells. 550 × 1.

Nitophyllum Wilkinsoniae Collins & Hervey.

Figure 8. Whole plant. $\frac{4}{5}$ nat. size.

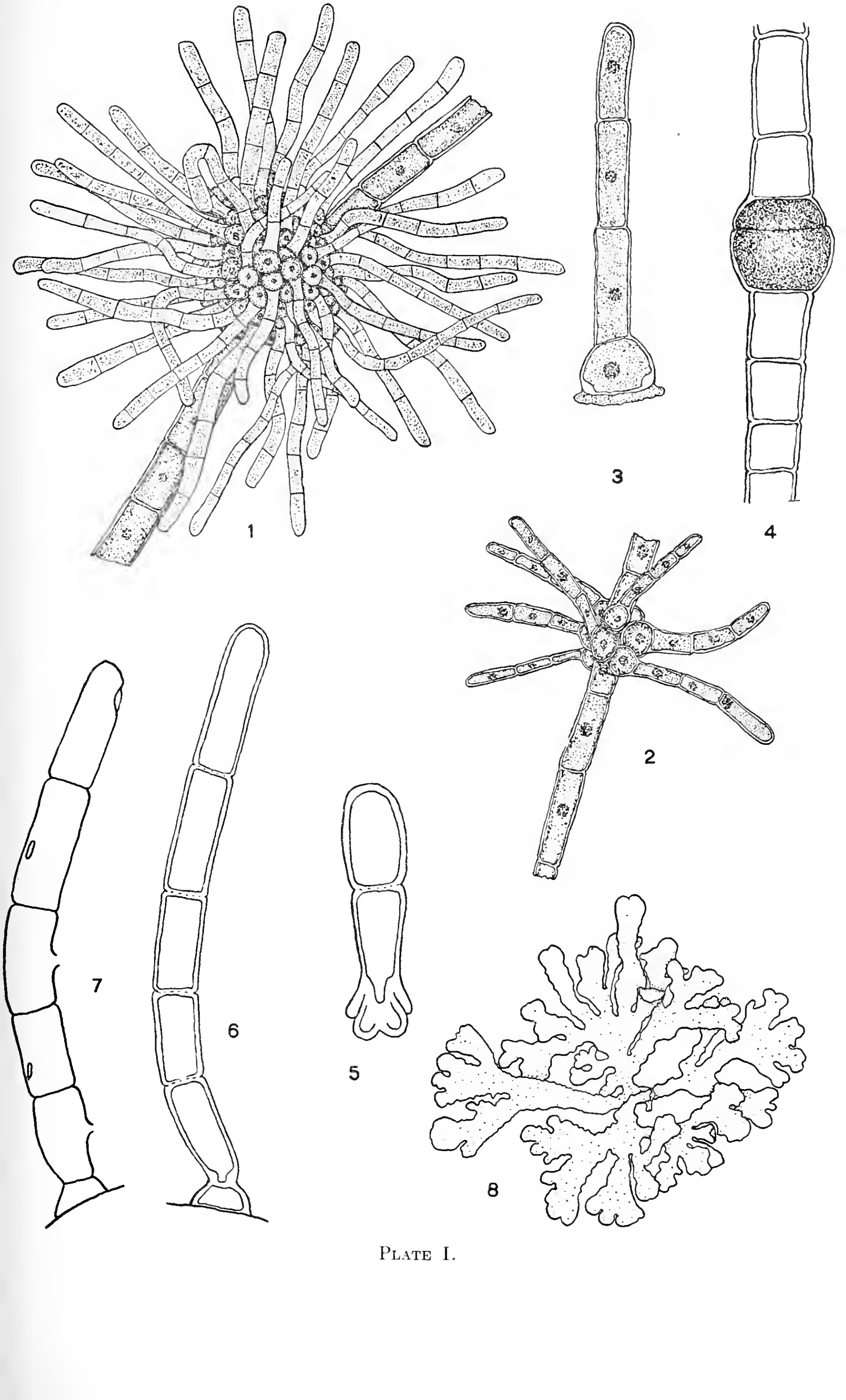


Plate I.

PLATE II.

Nitophyllum Wilkinsoniae Collins & Hervey.

Figure 9.	Margin of frond. 120 × 1.

Chondria curvilineata Collins & Hervey.

Figure 10.	Portion of branch with ramulus and terminal leaves. 255 × 1.
Figure 11.	Optical section of branch. 255 × 1.

Chondria polyrhiza Collins & Hervey.

Figure 12.	Branch with rhizoids and tetraspores. 240 × 1.

Lophosiphonia Saccorhiza Collins & Hervey.

Figure 13.	Tip of erect axis. 600 × 1.
Figure 14.	Ramulus with tetraspores. 600 × 1.

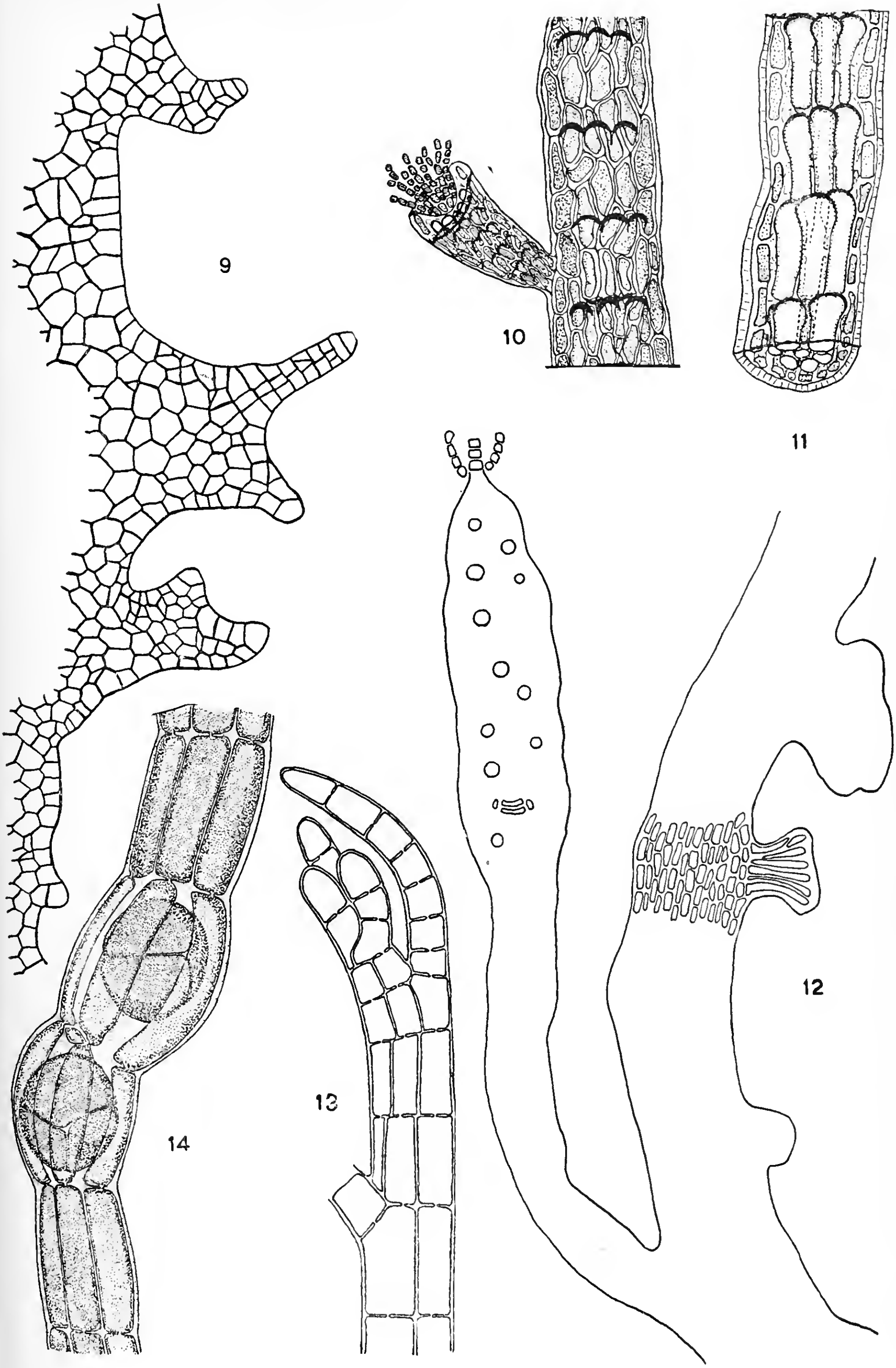


Plate II.

PLATE III.

Lophosiphonia Saccorhiza Collins & Hervey.

FIGURE 15.	Tip of erect axis with antheridium and leaves. 330 × 1.
FIGURE 16.	Cystocarp. 330 × 1.
FIGURE 17.	Prostrate filament with rhizoids. 120 × 1.

Lophosiphonia bermudensis Collins & Hervey.

FIGURE 18.	Prostrate filament with rhizoids and erect branches. 160 × 1.
FIGURE 19.	Antheridia. 160 × 1.
FIGURE 20.	Cystocarp. 160 × 1.
FIGURE 21.	Tetrasporangia. 160 × 1.

Ceramothamnion Codii H. M. Richards.

FIGURE 22.	Lateral union of two rhizoids from same node. 310 × 1.

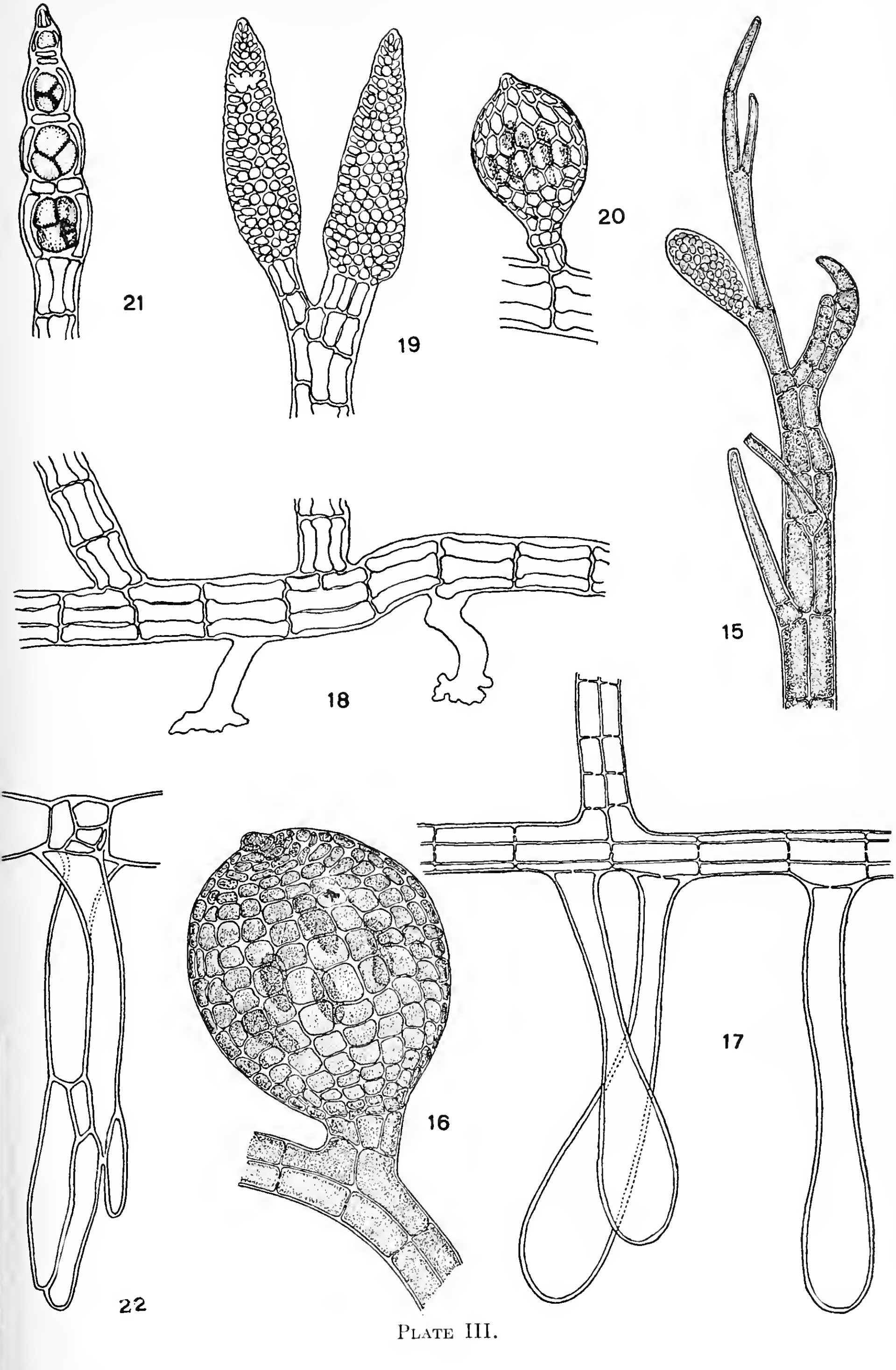


Plate III.

PLATE IV.

Ceramothamnion Codii H. M. Richards.

FIGURE 23. Union of three rhizoids from different nodes. 310 × 1.

Dasya spinuligera Collins & Hervey.

FIGURE 24. Branch with ramelli and young and mature stichidia. 120 × 1.
FIGURE 25. Cross section of branch. 160 × 1.

Gymnothamnion bipinnatum Collins & Hervey.

FIGURE 26. Prostrate filament with two erect and two descending axes. 300 × 1.

Ceramium cruciatum Collins & Hervey.

FIGURE 27. Prostrate filament with rhizoids and base of erect filament. 65 × 1.
FIGURE 28. Branch with tetraspores. 120 × 1.

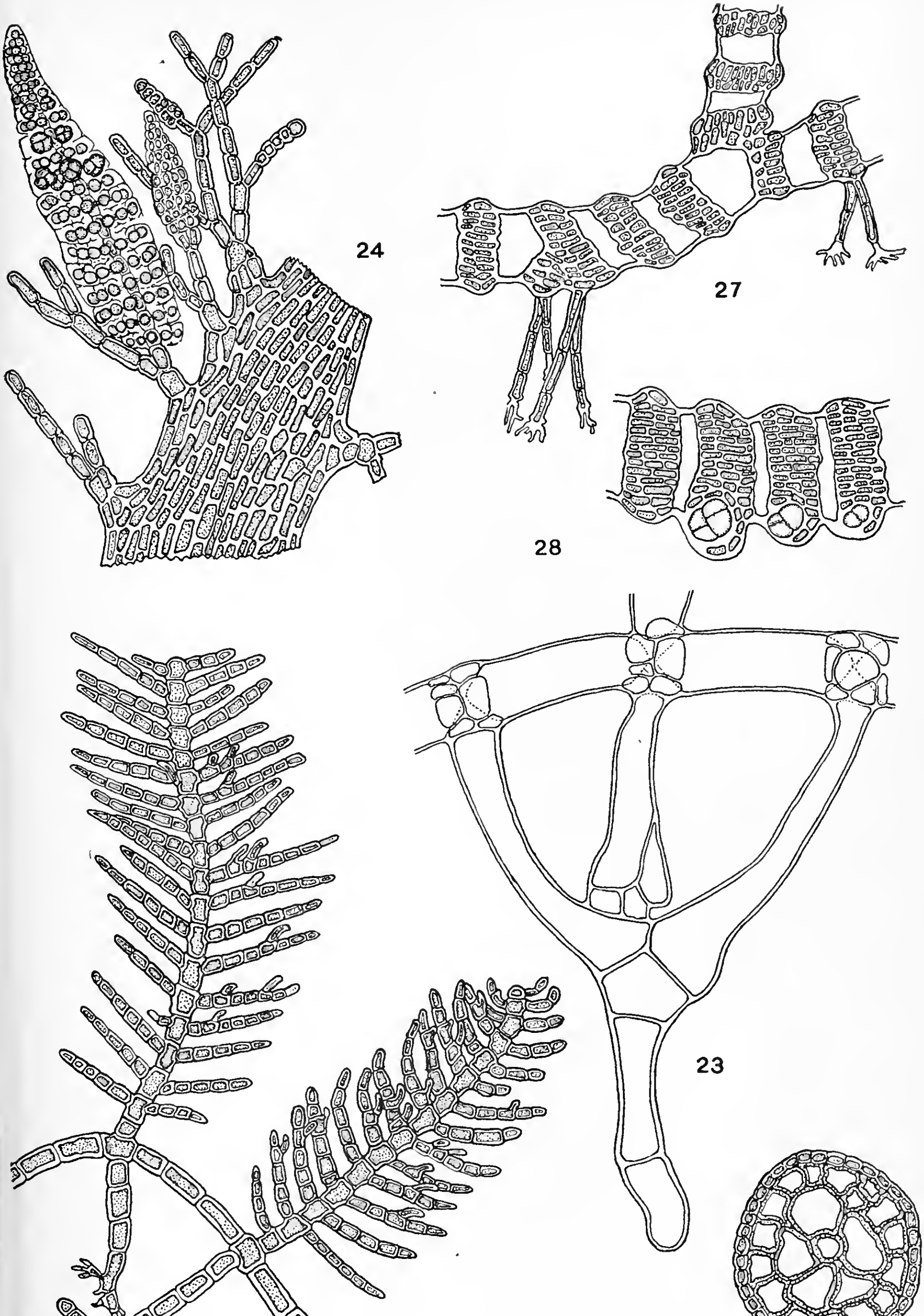


Plate IV.

PLATE V.

Ceramium transversale Collins & Hervey.

Figure 29.	Prostrate filament with erect filament and rhizoids. 120 × 1.
Figure 30.	Erect filament with branch. 255 × 1.
Figure 31.	Branch with tetraspores. 160 × 1.

Nitophyllum Wilkinsoniae Collins & Hervey.

Figure 32.	Section of frond through a sorus. 160 × 1.
Figure 33.	Superficial view of a sorus. 160 × 1.

Halymenia bermudensis Collins & Howe.

Figure 34.	Cross section. 255 × 1.

Halymenia pseudofloresia Collins & Howe.

Figure 35.	Cross section. 130 × 1.

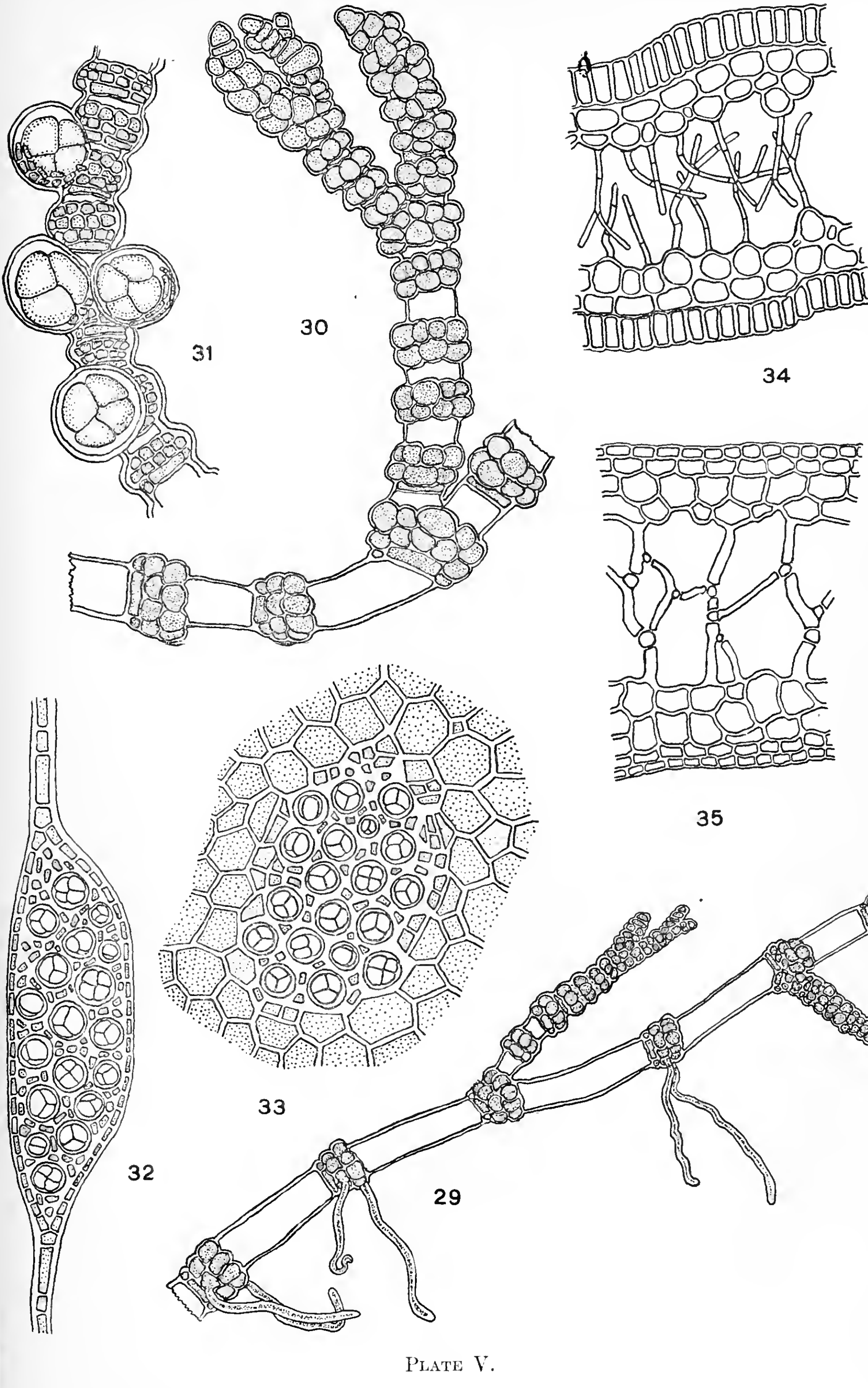


Plate V.

PLATE VI.

Halymenia pseudofloresia Collins & Howe.

FIGURE 36. Whole frond, $\frac{2}{5}$ nat. size.

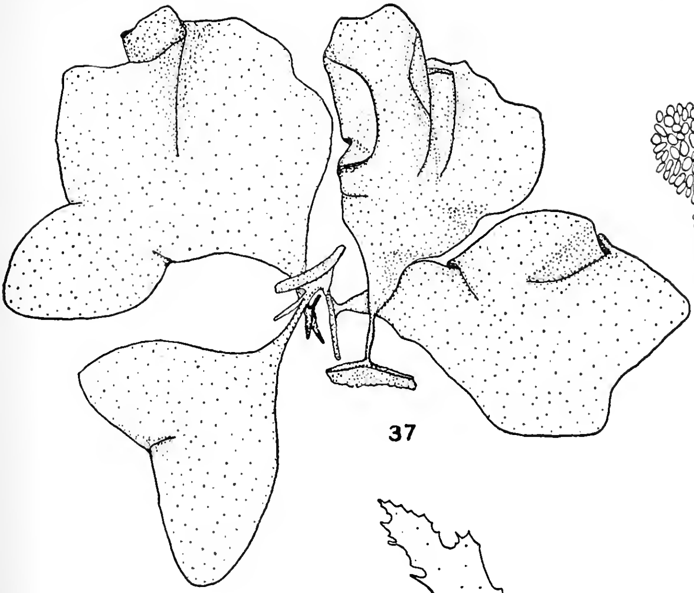
Halymenia bermudensis Collins & Howe.

FIGURE 37. Whole frond. $1\frac{3}{5} \times 1$.

Griffithsia tenuis Agardh.

FIGURE 38. Tip of tetrasporic branch. 160 × 1.
FIGURE 39. Node with antheridia. 300 × 1.

Habit figures were drawn from herbarium specimens, all others by camera lucida. Figures 5, 6, 7, 9, 12, 13, 14, 15, 16, 17, 22, and 23 are by F. D. Lambert; the others by A. C. Walton.



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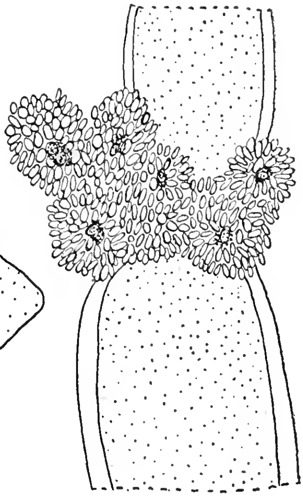

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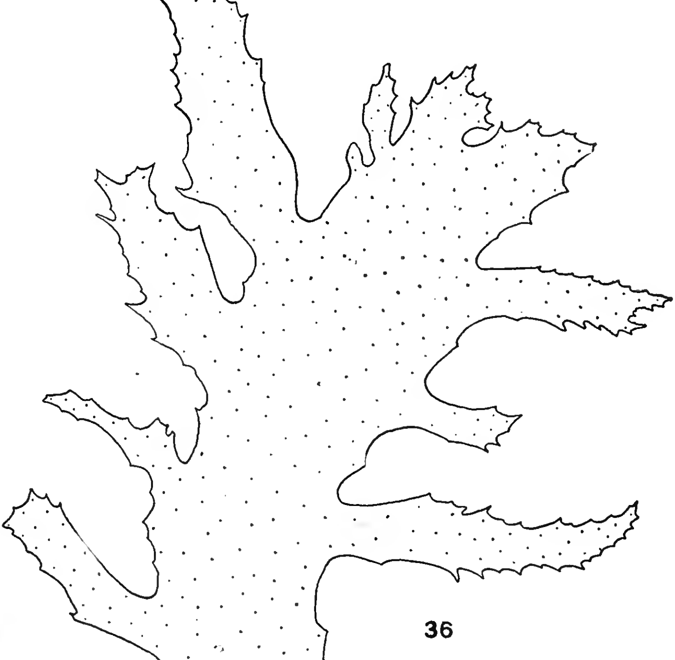

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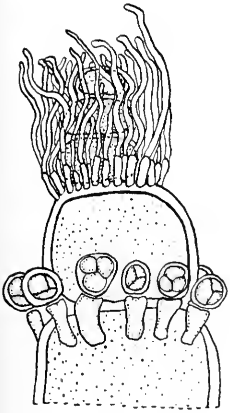

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Plate VI.

INDEX.

Synonyms are printed in *italics*, also names of species, etc., not found in Bermuda, but which are incidentally mentioned. **Full-face type** indicates the principal reference for a species.

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EVIDENCE OF ASSORTIVE MATING IN A NUDIBRANCH

By W. J. Crozier

BERMUDA BIOLOGICAL STATION FOR RESEARCH, AGAR'S ISLAND, BERMUDA[1]

Communicated by E. L. Mark, June 11, 1917

In man there is found, according to Pearson and others, a slight but appreciable degree of positive correlation between the members of mating pairs as regards their stature and certain other characters. For Paramecium a similar, but higher, correlation was proved by Pearl (1907) to exist between the lengths of members of conjugating pairs. Jennings (1911) substantiated Pearl's discovery that in Paramecium large individuals are usually found mated with large, small individuals with small, and made more certain the conclusion that this correlation (homogamy) is due to real assortive mating, as Pearl had previously maintained.

This matter of assortive mating, which may have various important implications for evolution, appears not to have been studied in animals other than Paramecium and man. With reference to characters concerning the size of the organism, at least, it should, of course, be possible for assortive mating to take place only when there is available some physical basis for the required process of selection. Hence, although echinoderms and some other marine animals appear to congregate at their times of breeding, and may even be conspicuously disposed in pairs (Orton), it is not to be expected that invertebrates practicing external fertilization would, in general, yield any evidence of assortive mating. Among gastropods, however, the case is different, and notably so with nudibranchs. In the latter animals, which are hermaphroditic, a true copulation of two individuals seems a prerequisite for fertilization of the eggs. In some nudibranchs the male and female genital openings, two or three in number, situated on the right side of the body, are separated by a considerable distance, and the behavior of the animals in copulation shows that it is necessary for the 'male' and 'female' openings of one individual to be brought simultaneously into close relation with the appropriate openings of another (e.g., in Cenia, as described by Pelseneer, 1899).

Other nudibranchs, such as chromodorids, have the reproductive openings concentrated upon a single small papilla; but, in some cases, at least, their behavior during the maneuvers preliminary to actual copulation strongly suggests that here also there is a rather well-defined, though not absolute, mechanical necessity for equality in the sizes of the individuals forming a successful mating pair. Reciprocal fertilization may be presumed to occur in most of these cases, and is certainly carried out in some instances.

The observation of mating pairs of Chromodoris zebra repeatedly suggested that under natural conditions this species forms copulating pairs of which the individual components closely correspond with each other in general size. Sexually mature specimens of this species range in length from 4 to 18 cm. Differences in the relative sizes of the various individuals are readily detected by the eye, while other dimensions of the animals may be subjected to measurement in the living condition.

One hundred and forty-eight pairs of copulating C. zebra were obtained in the field. The total length (anterior edge of the mantle to posterior termination of the foot) was determined for each specimen, according to a method[2] giving results sufficiently reproduceable for the purposes of statistical treatment. As a check upon this measurement certain other dimensions were ascertained, including the weight and the volume. Each of the methods of evaluating size yields the same qualitative result. Therefore the estimations of total length according to the procedure employed may be relied upon as a criterion of assortive mating with respect to size. In figures 1 and 2, summarizing the observations upon mating pairs, total length measurements are used.

Figure 1 is a regression plot showing the correlation between the lengths of individuals and the average lengths of their mates, as found under natural circumstances. If the correlation were perfect, the observed points would lie upon line "(1)"; if no correlation were to be detected the regression line "(2)" would coincide with m–m'; actually the degree of correlation between the lengths of individuals composing copulating pairs is of about the same magnitude as that found in cultures of Paramecium containing a mixture of pure lines.

Laboratory experiments were carried out with over 400 specimens, embracing about 200 individuals originally obtained in pairs, and an approximately equal number of "single" nudibranchs. About 50 specimens, ranging in length from 4 or 6 to 16 or 18 cm., were placed in each of a number of 9-gallon aquaria supplied with running water. After two days the mating pairs noted in each aquarium were removed, and measured. Data were in this way obtained from 119 pairs, which had come together under such purposely contrived circumstances that true random mating might easily take place, since so many individuals were crowded together in a small space; while if assortive mating is in any degree a real condition of copulation it should still make its influence sufficiently evident. Measurements of these pairs are plotted in figure 2. The correlation between the members of mating pairs is in fact better than in the previous case (fig. 1); reasons for this will be discussed in a subsequent paper.

A study of the behavior of Chromodoris supports the view that there is exercised an active selection of mating partners. As a rule, two animals greatly differing in size do not successfully copulate. This has been verified by experiments in which the size of some individuals has been artificially reduced through starvation. The physical basis of assortive mating in Chromodoris is probably found in the relative attitudes assumed by the conjugants and in reactions to tactile (and chemical?) stimuli which determine these attitudes.

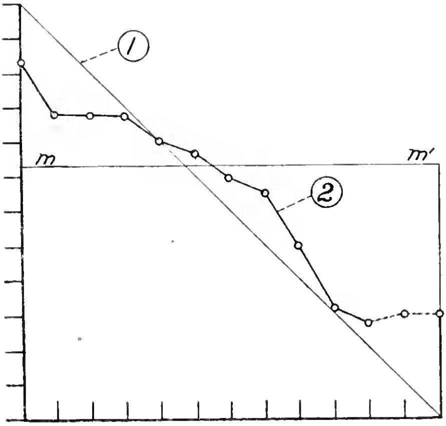

Fig. 1

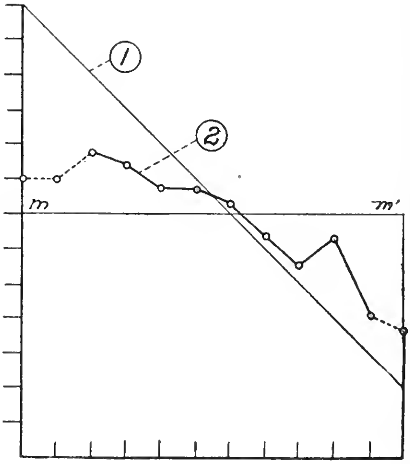

Fig. 2

FIG. 1.—ILLUSTRATING THE CORRELATION IN SIZE BETWEEN THE MEMBERS OF 148 PAIRS OF CHROMODORIS ZEBRA COLLECTED IN THE FIELD

The thin continuous line (1) gives the lengths (as ordinates) for the different classes of individuals in order of decreasing size. The heavy line (2) gives the average lengths of the mates of the individuals of these classes. The unit is 1 cm; *m—m′* is the mean for all.

FIG. 2.—ILLUSTRATING THE CORRELATION IN SIZE BETWEEN THE MEMBERS OF 119 PAIRS OBTAINED IN LABORATORY EXPERIMENTS

The thin continuous line (1) gives the lengths (as ordinates) for the different classes of individuals in order of decreasing size. The heavy line (2) gives the average lengths of the mates of these classes. The unit is 1 cm; *m—m′* is the mean for all.

Two suggestions may be made regarding the possible significance of assortive mating in Chromodoris. If the population is composed of a mixture of pure lines, then one effect of this type of copulation may well be, as in Paramecium (Jennings), the prevention of interlinear crossing. Certain generally accepted ideas regarding the life history of nudibranchs may tend to favor this view. The evidence for the presence of pure lines in the Chromodoris stock is, however, entirely inferential. It would, indeed, be almost impossible to obtain good evidence upon this point, unless, possibly, through a study of the rate of segmentation of the eggs; but the eggs of C. zebra are not well adapted for this work, and it is very doubtful if such evidence could be made conclusive.

Another, and, I believe, at present better founded, suggestion concerning the effect of assortive mating is based upon the fact that the size of the egg-masses, and the number of eggs in each ribbon, as well, probably, as the number of egg masses deposited by each animal during a single season, increase directly with the size of the individual. On grounds of physiological economy—remembering that mutual fertilization is involved, and remembering also that each animal deposits a number of egg-masses at each spawning season—it may be argued that the mating of large individuals is an influence tending to increase the number of larvae beyond that which would result from random pairing. In some other nudibranchs assortive mating, if it occurs, may have a different, or an additional, significance.

Summary.—Mating pairs of the nudibranch Chromodoris zebra are found to exhibit a rather high degree of correlation between the sizes of the two members. This is due to assortive mating, which may constitute an important influence tending to increase the numbers of larvae.

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[1] Contributions from the Bermuda Biological Station for Research, No. 70.

[2] It was necessary to remove the animals from the water and place them, dorsal surface downward, upon a glass plate.

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INTEGUMENTARY PHOTOSENSITIVITY IN A MARINE FISH, EPINEPHELUS STRIATUS BLOCH

HOVEY JORDAN

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CONTENTS

I. INTRODUCTION

A. Literature

Experimental evidence, although it is not extensive, has consistently indicated that the integuments of fresh-water fishes are photosensitive, but that those of the strictly marine members in this class, on the other hand, are insensitive to light. Parker ('09) states that the following marine fishes—Mustelus canis, Anguilla chryspa, Stenotomus chrysops, Tautogolabrus adspersus, Tautoga onitis, Chilomycterus schoepfi, Opsanus tau and Microgradus tomcod—possess integuments which are unresponsive to photic stimulation. He concludes, therefore, that cutaneous photosensitivity may be a characteristic of fresh-water fishes, as phosphorescence is of certain marine organisms.

But in the course of certain experiments upon the hamlet (Epinephelus striatus), I discovered, contrary to this theory, that both normal and blinded fishes are negatively phototropic. Their reactions closely resembled those of the fresh-water fishes which have already been described by several authors. Eigenmann ('00) has shown that the blind fish Amblyopsis is negatively phototropic; Parker ('05) found the common brook lamprey, Ammocoetes, to be negatively phototropic and also photodynamic; and Payne ('07), who studied Amblyopsis, states that this fish is negatively phototropic and photodynamic regardless of the direction of the rays of light and also that its sensitivity to light decreases with age.

Fundulus, however, is reported to be an exception to the theory of universal cutaneous photosensitivity among the non-marine fishes, since Long (see Parker '05) and Parker ('09, p. 77) were unable to stimulate its skin with light. It might, however, be urged in explanation of this apparent exception that Fundulus is adapted to life in salt water (as well as in fresh) and simply shares with other marine fishes their characteristic insensitivity to light.

It is therefore of considerable interest that at length a marine fish with no known proclivities for life in fresh water has been found in which there is a marked photic sensitivity. Though only a single case, this may well cause one to hesitate in adopting the view that there is any fundamental and constant difference in this respect between the fishes of salt and of fresh water. It will perhaps also suggest that photosensitivity of the skin of lower verebrates is a capacity which has been independently acquired (or retained?) by remotely related forms.

B. Purpose of experiments

In view of the interest attaching to the question and the importance of a critical examination of these responses, further experiments were at once undertaken. They aimed, first, to determine more carefully the positive or negative character of the phototropism observed; secondly, to discover any evidence of photodynamic responses; and, thirdly, to ascertain, if possible, any variation in the degree of sensitivity manifested by various regions of the integument. The probable location of the photo-receptive end organs, whether they lie in the integument or, as Payne ('07) has suggested, within the spinal cord, was also considered. During the course of the work several incidental problems arose, principally the questions of the physico-chemical nature of the effect of light upon the sense organs and the phenomenon of their exhaustion. Some suggestive data were obtained on these points but it is not the purpose of this paper to attempt their description and explanation in detail.

C. Material and methods

The hamlet, or grouper, proved to be a very favorable animal for these experiments because it is unusually hardy and recovers quickly and completely from severe operations, apparently manifesting no abnormalities of behavior.[1] In order to determine the characteristic reactions of the fish, normal individuals were studied first; but all subsequent investigations were conducted with hamlets whose eyes had been enucleated at least twenty-four hours previous to the time of the experiment. All fishes were kept in a large spawning pool which was supplied with a stream of fresh sea-water. It was usually necessary to prepare fresh individuals every second or third day, because fishes kept for a longer time manifested variations in response which were probably caused by hunger, fatigue and the loss of eyes.[2] In order that exhaustion of the photoreceptors might not modify the responses, each fish was used for only one, or at most two, sets of experiments embracing from six to twelve tests each.

The specimen under investigation—all experiments were conducted at night—was placed in an aquarium whose sides were of glass and whose top, bottom and ends were of an opaque material. After the fish had become habituated to the new environment its integument was illuminated with light from electric lamps of various moderate inten-

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[1] This characteristic can hardly be exaggerated. The fishes endure the severest of operations, either on the central nervous system or on the body, with remarkable resistance.

[2] The loss of eyes seems to cause an increase in the activity of some cutaneous faculties, i.e., sensitivity to tactile and rheotropic stimuli; but the phototropic responses, on the other hand, are consistently retarded. It is likewise almost impossible to induce blinded fishes to eat and their olfactory responses are more or less retarded. These facts are interesting as showing something of the rôle of optic stimuli in the life of the normal fish.

sities. These were placed within a small wooden reflector-box which had a small hole in one end. The box was lined with tin for the purpose of increasing the intensity of the illumination. It is to be regretted that no means was available for testing the exact intensity of the light;[3] but for the study of variations in the sensitivity in different regions of the integument and of photodynamic responses, relative intensities, such as are obtained from wattages of various magnitudes, are sufficiently precise. The illumination of the fish, however, was less intense than the indicated wattage of the lamp, because a certain amount of light was cut off by the edges of the reflector-box and by the water[4] between the fish and the light.

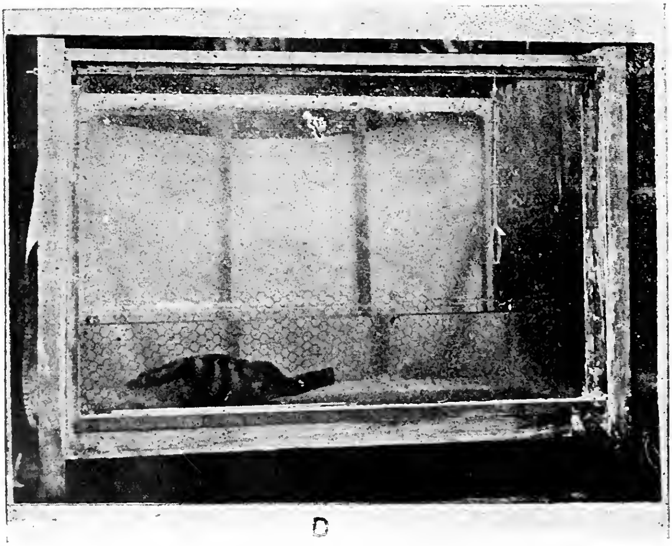

Figure of the aquarium used in testing fishes for photosensitivity

These experiments were conducted in an aquarium which has already been figured and described elsewhere (Jordan '17); the figure is repro-

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[3] The candle power of mazda electric light bulbs is approximately 1 per watt; but, as the candle power was not measured in the following experiments, wattages instead of candle powers will be used to express the intensity of illumination.

[4] Temperature changes are negligible, since a thermometer held in the position occupied by the fish was unaffected by the light. There was usually about 6 to 8 inches of water between the light, which was held against the glass of the aquarium, and the fish.

duced here. There were no currents in the tank during the experiments with light, but the sea-water was renewed at frequent intervals. For the purpose of determining the positive or negative character of the hamlet's phototropism, one-half of the water in the tank, which was approximately 15 x 15 x 12 inches in size, was darkened by an opaque black screen; the other half, containing the fish, being fully illuminated by electric lamps of various intensities. Thus were created so-called light and dark fields. If a fish, manifesting the fin and body movements characteristic of photic stimulation,[5] remained in the lighted zone, it was regarded as positively phototropic, whereas swimming into the darkened portion of the tank was taken as evidence of negative phototropism.

In the detection of differences in the degree of sensitivity of various regions of the integument, as well as for securing additional evidence concerning the positive or negative character of the phototropism, the light was localized, rather imperfectly, upon different regions of the body by means of absorbing screens of black pasteboard and mirrors which served as reflectors. It was difficult to procure a delicate local stimulation by these methods and the areas described are large and overlap each other more or less.

The writer is deeply grateful for the assistance which Dr. E. L. Mark and Dr. W. J. Crozier have rendered in connection with this work, and also for the privilege of study at the Bermuda Biological Station. He also wishes to thank the trustees of the Humboldt Fund for financial aid.

II. DESCRIPTION OF EXPERIMENTS

When a normal fish was placed in the testing aquarium, it swam about vigorously for a few moments, bumping the walls with its head or tail. This uneasiness soon disappeared, however, and it settled to the bottom, where, unless disturbed, it remained indefinitely. If now its body were sufficiently illuminated, it soon began to swim about, and usually did not resume a resting position until the light was removed or until it reached the dark end of the aquarium. The criterion of stimulation adopted for these experiments was to start the fish in this way from a position of rest and then, by cutting off the light, to cause a resumption of the original attitude.

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[5] The fishes when first illuminated often twitched their dorsal fins rapidly and changed position slightly. No increase in the rate of respiration was noted and the fin movements were but little changed in rate. Ultimately illumination led to more or less continuous swimming about.

A. Reactions of normal fishes

1. To light and dark fields. Light- and dark-field experiments, in which the half of the aquarium containing the fish was illuminated, were often repeated and almost invariably a decided negative reaction was observed. The fishes with few exceptions swam away from the lighted end of the aquarium when a 60-watt light was used as a stimulus. This reaction occurred in approximately 60 seconds, occasionally after a much longer time. Then after a variable period of relative quiescence in the dark, the fish often returned to the lighted zone for an interval, shorter, usually, than the sojourn in the shaded end. Illumination usually caused uneasiness, the fish being constantly in motion. In many instances this swimming from light to dark and back to light was repeated several times; but until the photoreceptors became exhausted, successive illuminations seldom failed to cause a retreat to the dark—a very definite negative reaction.

2. To regional stimulation. Negative responses were also obtained in nearly all cases when a portion only of the integument was illuminated by a 100-watt electric light. By testing different areas of the skin separately, the other regions being in comparative dark, it was found that various areas manifested this sensitivity in different degrees. The times of exposure required to produce evidences of stimulation on certain general areas of the body were as follows: Head and eyes, 1–5 (average 3) seconds; posterior end of the body, 4–17 (av. 7.6) seconds; and mid-trunk 10–20 (av. 12.5) seconds. In these experiments the whole of the head, the body posterior to the anus and the region between the pectoral fin and anus, were successively, and more or less exclusively, stimulated by the localized light. Each fish was tested several times in rapid succession; though some reactions were inexplicably variable in time, there was on the whole a noticeable uniformity in the duration of illumination which was necessary to produce a negative response. For instance, among the records of the reaction times when the stimulus was applied to the head region are many data which are as uniform as the following: 4, 3, 2, 1, 3, 2 seconds. Sometimes the stimulation required was much longer, 60 seconds being the greatest. But as a rule the reactions to localized stimulation were consistent and precise and the failures to respond were few.

Normal hamlets, then, are negatively phototropic when either the whole, or a considerable part, only, of their integuments are stimulated by electric light. Some areas of the skin, too, usually manifest a greater degree of sensitivity than others. This susceptibility to photic stimulation decreases in the following order: head > tail > mid-body regions.

B. Reactions of blinded fishes

During the experiments on regional sensitivity, the eyes of the normal fishes employed were usually in comparative darkness. It is improbable, therefore, that they could have been sufficiently illuminated by diffused light to cause a reaction, even though their partial illumination may have had some influence on it. However, in order to determine whether the integument or the eyes were chiefly concerned in such responses as have been described, similar experiments were repeated on blinded fishes. The behavior of such "physiological" individuals when first placed in the testing-tank was very similar to that of the normal animals. Their period of preliminary uneasiness, however, was slightly longer and they more frequently collided with the walls of the aquarium, since at first they apparently had no idea of the dimensions of their confines.

1. To light and dark fields. A single light-field and dark-field experiment will be described in detail, in order to show the nature of the response of blinded fishes to light; there are exhibited several indications of stimulation which precede the true negative response—the swimming to the darkened end of the aquarium. When a hamlet whose eyes have been enucleated finds itself in that half of the tank which is lighted by a 60-watt lamp, its first visible reaction, the raising of the dorsal fin, occurs in 24 seconds. A few seconds later its chromatophores darken.[6] Next it swings its tail toward the light, and finally, after 75 seconds, swims to the darkened half of the aquarium, where it comes to rest. This position is retained for about 3 minutes, whereupon the fish often swims back, more or less completely, into the lighted zone. After a period of relative uneasiness there, which is usually shorter than the interval of quiet in the dark, the negative reaction is repeated.

Often in such experiments the attempt to return to the light is stopped when the head first becomes illuminated. This momentary hesitation is usually followed by a retreat to the darkened end. Some of the fishes when their heads entered the light, hesitated, then reversed ends, and finally backed part way into the light, as if to test

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[6] Light causes the region of the integument which is illuminated to become darker in color. Sunlight also darkens the color of the skin and shading lightens it.

the stimulation by means of the tail.[7] They then usually returned to the shadow, but sometimes continued toward the light until they were completely illuminated. This alternation of positions is almost identical with that which the normal fishes executed; but in the latter I did not notice any backing into the light.

Such behavior is typical of the several individuals which were tested in this manner. With few exceptions they all swam away from the light; thus being, as the normal fishes are, negatively phototropic to general illumination. Their reaction time, though somewhat variable, averages slightly longer than that of normal fishes, being 70 seconds for the stimulus of a 60-watt lamp at a distance of about 30 centimeters. A 100-watt light causes the same reaction in less time.

2. To regional stimulation. The integuments of blinded fishes also were explored with a localized light in order to determine whether the variations in regional sensitivity which the normal fishes exhibited would persist after the enucleation of both eyes. The apparatus used and the regions tested in these experiments were the same as those which have already been described in the account of the reactions of normal groupers.

They revealed a regional sensitivity nearly the same as that of the normal fishes; the head being the most sensitive, the tail intermediate and the mid-body least sensitive. But the average time of reaction to the same intensity of illumination was, for each region, longer than that of the normal fishes. A few experiments to determine this relation showed that on the average[8] the period of exposure necessary to produce stimulation is increased by the removal of the eyes as follows: in the head region, from 3 seconds to 8.4 seconds, or 180 per cent; in the mid-body region, from 12.5 seconds to 22.5 seconds, or 80 per cent; and in the tail region from 7.6 seconds to 11.5 seconds, or 51 per cent.

This retardation, it is to be observed, varies, but not proportionally

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[7] It is interesting in this connection to note that the hamlet also backs into a current (Jordan '17) and swims backward into the cavities of its natural environment. It also uses the tail frequently as a tactile organ. The posterior part of the body may, therefore, have an important sensory function. Cutaneous sensitivity to most other stimuli (tactile, rhetropic, chemical) is very similar in its distribution to that to light. A somewhat similar case is one described by Parker ('05, p. 418). He states that the region of Ammocoetes which is most sensitive to light is its tail, and he coördinates this fact with the burrowing habit of the fish.

[8] There were, however, as usual, a few erratic cases in which the reaction time of the mid-body region was shorter than that of the tail, and others in which the reaction times of the three regions were equal.

to the sensitivity of the three regions, the order of the retardation being: head, mid-body, tail; that of sensitivity in both normal and blinded fishes: head, tail, mid-body. The explanation of this order of retardation is doubtless to be sought in the fact that it was impossible completely to screen the head when the mid-body and tail regions were exposed to light, with the result that the head (and consequently the eyes) were more highly stimulated by mid-body than by tail illumination.

The reaction times of the integument of normal and blinded fishes in different regions can not be regarded as wholly satisfactory, for the reason that, as above stated, the illumination of each region involved a greater or less illumination of the other regions. While, therefore, they show clearly which is the most and which the least sensitive area, they may not accurately represent the degree of sensitivity.

By way of summary, then, it may be said: first, that the integument of Epinephelus striatus exhibits a negative photosensitivity, which is independent of the eyes; secondly, that it also shows, fairly constantly, three regions of the integument which manifest this sensitivity in different degree as follows: head > tail > mid-body.

3. Photodynamic nature of the reponses. As noticed in most of the preceding experiments, the quickness of the response depends rather closely upon the intensity of stimulation. An increase in the wattage usually decreased the required period of stimulation and *vice versa.* This suggests that the responses may be photodynamic in nature.

Another set of experiments was, accordingly, undertaken for the purpose of testing the validity of this assumption. To do this the same local region, or the skin of one whole side, was stimulated successively with different intensities of light and the time of reaction carefully noted. In order to minimize the error which might be caused by exhaustion, care was taken to use alternately high and low intensities and especially to allow ample intervals for recovery. The results, some of which are given further on, substantiate the conclusions derived from the earlier observations, establishing the fact that the reactions of the hamlet to photic stimulation of the integument are dynamic in character.

The period of illumination required to produce a response in these experiments was found (as the result of about twenty-five tests at each wattage) to be for 100-,60- and 40-watt lamps 24, 35, and 53 seconds, respectively. In other words a decrease of 40 per cent from the highest intensity of the light (from 100 to 60 watts) resulted in an increase of about 45 per cent in the reaction time (from 24 to 35 seconds), and a 60 per cent decrease in the brightness of illumination (from 100 to 40 watts) increased the reaction time about 120 per cent (24 to 53 seconds). This rough inverse ratio between time and intensity, though based on methods not rigidly exact, conforms fairly well to the Bunsen-Roscoe law of photochemistry, viz., that the products of reaction time and intensity of stimulation are constant for any effective illumination. In my experiments upon the whole of one side the products for 100-, 60-, and 40-watt lights were 2400, 2100 and 2120, respectively. This conformity to the Bunsen-Roscoe law may, perhaps, be taken to indicate that photic stimulation of the integument of Epinephelus is photochemical in nature, as Fröschel ('08), Blaauw ('09), Loeb ('11), and Parker and Patten ('12) have suggested for varous biological phenomena.

The phototropic reactions of the hamlet, then, are dynamic in character and the stimulus is probably produced by a photochemical process.

C. Exhaustion of the photoreceptors

1. General evidence. A study of the responses both of normal and of blinded fishes to successive stimulations by the same intensity of light often shows a progressive increase in the time of reaction from the first to the last response. A state of complete exhaustion is, of course, reached when no response can be induced. There seems to be, however, no definite ratio between the number of stimulations and the increase in reaction time. Indeed, in two or three individuals the first response was slower than the second, or all responses occurred after about the same interval of time. Even in the latter cases, however, a condition of complete exhaustion was finally effected after a sufficient number of exposures of adequate intensity, but its appearance was abrupt rather than gradual.

2. Photodynamic nature of exhaustion. The process of exhaustion, moreover, appears in general to be photodynamic in character, for the period of resistance of the receptors is lessened by an increase in the intensity of the light and *vice versa.* This inverse ratio is, apparently, similar to that which has just been described in connection with the negative responses.

In experiments on this point it was found necessary in order to produce a state of exhaustion to stimulate the fish for 275 seconds with the light from a 100-watt bulb; but when a 60-watt bulb was substituted, this period was more than doubled, being 562 seconds. Thus a decrease of 40 per cent in the intensity of illumination (from 100 to 60 watts) increased the time of resistance of the photoreceptors more than

100 per cent (from 275 to 562 seconds). Stated in terms of the Bunsen-Roscoe law (product of intensity into time of exposure) the agreement is not very close (27,500 and 33,720), but still it suggests that exhaustion, like stimulation, may be a photo-chemical process.[9]

D. Location of the photoreceptors

Payne ('07, pp. 320–321) in endeavoring to explain the fact that, in Amblyopsis, the negative phototropism is greater when the fish is illuminated from above than when from the side, has suggested that brain and spinal cord may be "affected directly on account of the transparency of the tissues above them." This is equivalent to suggesting that the photoreceptors may be located in the brain and spinal cord; but Parker ('05) has contended that in Ammocoetes the receptors are contained in the integument, for he was able to stimulate this fish by directing light against its belly, which, he argued, contained viscera impenetrable to the light which he employed. He had previously ('03, p. 33) shown that the brain and spinal cord of frogs are also insensitive to light.

In view of this difference of opinion an attempt was made to determine the location of the sensory elements in blinded hamlets. For this purpose the capacity of light (from a 100-watt bulb) for stimulating the integument after it had passed through a considerable mass of muscular tissues was tested. The apparatus used for this experiment consisted merely of a piece of the lateral body muscles, about half an inch in thickness, from another hamlet, held in front of the aperture

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[9] An incidental question—the relative fatiguing effects of continuous and of very slowly intermittent light—was also considered. The data of five experiments, of 16–20 exposures each, indicate that continuous illumination and successive illuminations of the same intensity which are separated from each other by one-half or one minute intervals, are about equal in their power to effect complete exhaustion of the cutaneous photoreceptors. The experiments, however, are too fragmentary and the results too inconstant to warrant any general conclusions on this point. If after many tests this relationship should prove to be constant, the difference between it (although there is no ground for assuming a parallelism) and the results of Parker and Patten ('12) is perhaps explained by the fact that a minute, or even one-half minute, interval between exposures is sufficient for the partial recovery of the sense organs. I was ignorant, at the time of this experimentation, of the work of Parker and Patten; otherwise I might have undertaken, as they did, experiments with light which was interrupted at intervals of high frequency. It would be of value to compare from this point of view the photoreceptors of the eye and skin.

of the reflector-box. This tissue constituted the so-called "meat screen." With this apparatus were repeated experiments similar to those on negative phototropism and regional sensitivity which I have described above. The sensitivity of the spinal cord itself to nearly direct stimulation—i.e., without the meat screen—was also tested. The results obtained indicate that the spinal cord of Epinephelus striatus contains no photoreceptive elements, even though light can reach it through the integument and muscles.

It was always possible, contrary to expectation, to cause stimulation with light which had traversed the screen of meat. The reaction varied from the normal response only in its comparative slowness. In one experiment, upon the posterior end of the body, the reaction-time was 28.5 seconds longer than when no "meat screen" was used. This merely shows that light is absorbed as it passes through the tissue, but not sufficiently to render it ineffective. By local stimulation of different areas of the integument with this apparatus, it was even possible to obtain reactions which were consistent with the previously described differences in regional sensitivity to unscreened light. The thickness of the "screen" of tissue (about one-half inch) was the same as that through which light would have to pass in order to reach the spinal cord of an average sized fish. The possibility, then, of such stimulation, provided that the cord contains the appropriate photoreceptors, is assured. Consequently, the presence of half an inch of intervening muscular body-wall cannot be used as a conclusive argument to prove the absence of photoreception in the cord.

The muscles of one side of the body were next removed from a fairly large region anterior to the caudal fin, leaving the cord partially exposed. Uninterrupted light was directed upon the column and cord. A response occurred but it was not quickened, as one would expect if the photoreceptors were located within the cord; on the contrary it was slower by 28.5 seconds than the response of normal fishes. It is significant that this retardation is just the same as that which the "meat screen" caused in experiments where the lateral body wall was not removed. It indicates that in the present experiment the light passed through the cord without affecting it; but that, after traversing the body muscles of the intact side, it stimulated the integument of that side from within. This suggests that the reactions of the blinded fishes were due to photic stimulation of the integument only.

In order to further check this result, the muscles and integument of both sides of the body were removed and the cord and column were directly illuminated. It was impossible to obtain any reaction. This check experiment was kindly done for me by Dr. Crozier after I left Bermuda.

It appears, then, that the posterior portion of the spinal cord of Epinephelus striatus is not sensitive to electric lights of moderate intensities.

III. CONCLUSIONS

1. At least one strictly marine fish, Epinephelus striatus, possesses an integument which is negatively photosensitive.
2. This sensitivity, expressed by negative reactions, is photodynamic in character, the time of the response being inversely proportional to the intensity of the illumination.
3. The sensitivity is not the same in different regions of the integument; being greatest in the head, less in the tail, and least in the mid-body region.
4. The photoreceptors are completely exhausted by a sufficiently prolonged exposure. The time of illumination necessary to produce exhaustion is in most cases inversely proportional to the intensity of the illumination—a photodynamic relation.
5. The results indicate, also, that the effect of light may be photochemical in nature.

IV. DISCUSSION

The cutaneous sensitivity of fresh water fishes to light has been used by Parker ('05, p. 418) to support Balfour's theory ('81) that the nervous elements of the eye originated from the integument and were once a functional part of it. Provided that the orientation of such cells is constant in the ectoderm and cord during embryonic and racial development, this theory explains the perplexing inversion of the elements of the vertebrate retina. Parker also states ('05) his belief that these light terminals (spinal nerve endings) are degenerate in modern lower vertebrates and also that they may represent the temperature terminals only of higher vertebrates, having lost the photosensitivity which they once possessed. This view involves, if the specialization of function is complete, the assumption that the integument of the higher vertebrates is insensitive to light—unless some other sense organ is regarded as the receptor—and also that the lower vertebrates possess some type of sensory cell which, as a receptor of radiant energy, is at first more or less universal in function (Parker '03, p. 34), but becomes so changed in the course of phylogenetic development as to function solely as a temperature terminal.

So far as the hamlet is concerned, it should be noted that the integument of its head is sensitive to a temperature change of about 11°C. (from 21° to 10°), because water at 10°C. causes a very precise negative reaction. Since its integument contains receptors for both photic and thermal stimulation, it presents a case in which, according to the view of a primitive and more or less universal radiant-energy receptor, the two functions may inhere in the same nerve terminal; but it should be emphasized that the other view—original independence of heat and light receptors—is likewise defensible. It is, moreover, of interest in connection with the above theory of a specialization of function, that in some of the vertebrates above fishes the integumentary photosensitivity is not entirely lacking. To what extent it persists is as yet known only imperfectly. Graber ('84), Dubois ('90), Korányi ('95) and Parker ('03) have shown that certain Amphibians possess it. Some reptiles also, according to Carlton ('03) and others have skins which are sensitive to light. It is noticeable, too, that as between fishes and amphibians this photosensitivity is negative in the former, but positive in the latter (Parker '03).

More direct evidence of degeneration is seen in Amblyopsis, where, according to Payne ('07) the cutaneous photosensitivity is more pronounced in the young than in the adult. This fish, however, having functional eyes in the younger stages but lacking them in the adult, has probably been independently specialized for a peculiar mode of life and presents an unusual simultaneous degeneration of both optic and cutaneous photosensitivity, rather than ontogenetic evidence parallel to the assumed phylogenetic degeneration.

Parker ('08), after having studied the direction eyes of Amphioxus, concluded that Boveri ('04) was right in claiming that they arise *in situ*, and since the uniform orientation required by Balfour's theory does not in his opinion exist in Amphioxus, he considers the two forms of sensitivity (cutaneous and optic) to be independent of each other. This reasoning presupposes, of course, that the direction eyes of Amphioxus are the more or less immediate predecessors of the rods and cones. At first sight the promiscuous arrangement of the functional eye-cups in Amphioxus does seem to be an objection of Balfour's theory; but it is conceivable that these eye-cups may be secondarily oriented in different directions because light enters the cord from all directions, but that this interference with the uniform orientation of the photoreceptors, resulting from the special conditions of translucency in Amphioxus, may have had no permanent effect on the orientation of these receptors in vertebrates generally. A completely satisfactory determination of the phylogenetic significance of these cells seems to involve the question of the existence and nature of similar sensory cells within the neural tubes of other vertebrates.

If, hypothetically, according to the Balfour theory, the integument in phylogenetic development gradually loses its sensitivity to light, the cord should by so much gain this property and, as the eyes develop, the cord should in turn lose it, becoming specialized for the coördination and transmission of impulses rather than for receiving them. Of course, these two evolutionary processes might not have been absolutely continuous, and the conditions in the hamlet and some other vertebrates indicate that they may not have been entirely dependent on each other. It is, however, somewhat against Balfour's theory that the degeneration of integumentary photosensitivity does not more perfectly parallel the evolution of directive eyes in the cord,[10] and also that the characteristic vertebrate eyes are coëxistent with a pronounced cutaneous sensitivity in certain fishes, amphibia and reptiles. The probable difference in the structure of the photoreceptive elements in the skin and in the central nervous organs is also, as Parker ('05, p. 418) has pointed out, another possible objection.

The idea of the *in situ* development of the retinal elements in the neural tube and their non-derivation from primitively functional cutaneous elements received corroboration from Parker ('09) when he tested several marine fishes and found the skins of all of them to be insensitive to light. This he interpreted to mean that the vertebrate eye developed not from integumentary elements, but, as Lankester ('80) and Boveri ('04) had suggested, in a manner similar to the *in situ* origin of this organ in ascidian larvae.

The present paper, in demonstrating the existence of cutaneous photosensitivity in one marine fish, makes this argument less convincing; but the presence of sensitivity here, forming at present an exception among marine fishes, affords only a suggestion of the importance of further study on the origin of the eye of vertebrates and its relation to the photosensitivity of the skin. The inconstancy of integumentary photosensitivity may be taken as an argument for its secondary acquisition and against its being a remnant of a primitive function. A final

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[10] Crozier ('17) has recently shown that the integument of Amphioxus contains no normal photoreceptors.

solution of these questions, seemingly, must await further studies—from this point of view—upon the development, structure and function of the photoreceptive elements both in the skin and cord. Among such problems the questions of the development of the direction eyes of Amphioxus, and a search for conditions intermediate between them and the typical retinal elements of the lateral eyes, as well as a phylogenetic study of cutaneous photosensitivity, are clearly demanded.

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THE PHOTIC SENSITIVITY OF BALANOGLOSSUS[1]

W. J. CROZIER

Agar's Island, Bermuda

In view of the fact that the Balanoglossida have enjoyed so considerable a morphological prominence, by reason of the affinities to the early vertebrate stock attributed to them, it is rather a matter for surprise that information regarding their behavior and activities should be, as it is, conspicuously lacking. Owing to the somewhat unusual condition of the nervous system in these animals, moreover, their responses should, when analysed, provide some data of general interest. Perhaps the absence of data upon the behavior of balanoglossids is in part due to the difficulty of obtaining them entire and in quantities ample for purposes of experimentation. Certain of the more highly modified balanoglossids (Ptychodera, Glossobalanus) are available at Bermuda, and after devoting some time to a study of their local distribution, I have been able to procure several species in quantities sufficient for study.

One of these forms, probably Ptychodera bahamensis Spengel, has proved to be very plentiful, and the greater part of the observations here described were made upon individuals of this species. The present paper aims merely to record certain responses of Ptychodera when exposed to stimulation by light.

These animals occur in localities which are at some distance from the laboratory of the Biological Station, and when brought to the laboratory for observation they apparently suffer somewhat from the disturbances incident to transportation. This is particularly true in the warmer summer months. When kept in aquaria, either with or without sand, they, like other enteropneusts (cf. Caullery et Mesnil, '04), exhibit hardly any active movements, unless they be violently disturbed. By careful

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[1] Contributions from the Bermuda Biological Station for Research. No. 72.

observation, however, certain characteristic types of reaction may be made out.

If the animals are handled with care during collection and subsequently, they may be kept in a healthy condition for some time. Certain preliminary trials with specimens obtained in the summer time led me to state (Crozier '15) that Ptychodera was sensitive to sudden changes of light intensity, but that it was not phototropic.[2] Subsequent work with aninals in better condition, and particularly with numerous individuals collected during the cooler winter period, has shown this statement to be incomplete. Ptychodera is, in fact, definitely phototropic when the animal is in physiologically good condition.

No observations seem previously to have been made with reference to the sensitivity of Balanoglossus toward light. Considering their habits in natural circumstances, one would be led to suppose that these enteropneusts would tend to move away from a source of light, or that they would retract as the result of suddenly increased illumination. Assheton ('08) states that the Dolichoglossus studied by him protruded its long proboscis from the mud only at night. The Ptychoderas studied by me are found in sands of rather well defined types, either just below the surface of the sand or between this surface and the under side of flat stones. When uncovered, they promptly burrow again, or, if merely the proboscis and collar have been exposed, draw back into the sand.

A series of tests was made in which the animals were placed in an oblong aquarium jar and illuminated from one side. The vessel was in a dark-chamber In the first trials the aquarium contained clean sea-water without any sand. The animals were selected from freshly collected stock living in large glass dishes provided with a good supply of their native sand. I soon found that the Ptychoderas could move about much better if some sand was also placed in the experimental aquarium.

After being in the dark-chamber for some time before light was admitted, sunlight reflected from a mirror was allowed to

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[2] In the hands of the ingenious type setter, this word has, in the note cited, become transformed into 'photographic.'

fall upon the Ptychoderas. They immediately gave evidence of increased peristaltic activity, and those individuals judged to be in good condition soon turned the proboscis away from the light, and began to creep in the same direction. When illuminated in this way the proboscis becomes very mobile, and peristaltic waves pass rapidly along the genital pleurae, thorax and abdomen. The collar also exhibited wavy motions, particularly along its anterior edge.

When Ptychodera, or Glossobalanus, is illuminated from the side, it promptly turns the proboscis end toward the opposite side. Neither here nor in its movements after orientation is accomplished does Ptychodera make any 'mistakes'; its movements are directed immediately away from the light.

Fragmented animals were also employed, and it was found that anterior halves, separated in the region of the genito-hepatic transition, oriented in a normal manner and moved away from the light. Posterior halves, and pieces of the abdomen (including the caudal extremity) were stimulated to slightly increased peristaltic movement, and progressed away from the light tail first. Isolated posterior fragments tend to move in a caudad direction, even in the dark, but otherwise show relatively little in the way of organized activity until they have begun to regenerate.

When complete Ptychoderas, or anterior fragments, are placed ventral side uppermost they continue for a time their usual peristaltic movements, but progress in a caudad direction. Animals so situated, when exposed to light thrown on the anterior end, contract lengthwise to a notable extent, but continue to move backward. The reversed direction of locomotion, which results from the abnormal position of the balanoglossid, is a consequence of its normal peristaltic motions, and of the fact that it cannot, when so situated, adhere to the substratum at the anterior end.

It may be mentioned that a Ptychodera from which the collar nervous system (the delaminated part) has been removed, but otherwise intact, will orient in the usual way. These specimens, as well as the normal individuals, were found to burrow with the proboscis turned away from the light.

Examination of the surface of many individuals of Ptychodera with a small intense beam of light (cf. Patten, '15) showed that the only part which is conspicuously sensitive is the very tip of the proboscis. In the Tornaria larva there are found, in the apical region, which becomes the tip of the proboscis, two well defined groups of sensory cells, which have been termed eyes (cf. Bourne, '89; Morgan, '94; etc.). Ritter and Davis ('04, p. 195) state, however, that the Tornaria examined by them is not reactive to light. Certain annelid larvae are, as is well known, markedly phototactic, and posses organs corresponding to the 'eyes' of Tornaria (cf. Gerould, '06, p. 105). The behavior of Tornaria might, therefore, bear reexamination on this point.

The 'eyes' of the larva disappear, however, as the adult form is gradually assumed. No trace of them has yet been located in the proboscis of later post-larval stages. Nevertheless this region of the animal remains markedly sensitive to light. The whole tip of the proboscis, nearly one-fifth its length, seems about equally sensitive and I have been quite unable to establish any bilateral distribution of sensitive parts. The course of phototropic orientation in Ptychodera agrees with this condition, for the proboscis is slowly pushed from side to side as the animal moves away from the light. The extent of the sideward excursions is never considerable, unless the incident light be strictly horizontal, in which case the creature's proboscis may largely be shaded by its own body. When the light is made to fall at a slight angle, so that this shading is avoided, orientation is much more precise. Ptychodera illustrates the principle that an animal having an axial photosensitive spot may yet by suitable movements convert this terminal area into a bilateral sense organ.

Photic sensitivity in Ptychodera may easily be separated from that to tactile or chemical excitation If the animals be strongly illuminated for some time, they cease to respond to light after a brief intermission in darkness. Cocaine hydrocloride or chloretone, added to the water, likewise abolish photic irritability before tactile and chemical responses are notably interfered with. This is, of itself, insufficient proof of the separateness of the sensory organs concerned in the reception of photic stimulation, but it does show that photic irritability depends upon a process distinct from that implicated in the other modes of stimulation.

The general surface of the balanoglossids which I have employed is also sensitive to light, as previously stated, although this sensivity is much lower than that of the proboscis-tip. Local movements begin rather promptly when bright light is thrown upon portions of the animal; and even when an animal is photically so exhausted that orientation no longer results, there is still some increase in movement when the luminous intensity is suddenly increased.

Light has also another effect on Ptychodera, and on Glossobalanus. It is known that sunlight inhibits the production of light by certain animals. One such case was carefully studied by Peters ('05), who showed that the phosphoresence of the ctenophore Mnemiopsis was inhibited by sunlight, although its recovery of luminous powers in the dark was accelerated if the animal was simultaneously agitated by mechanical means.

All the Enteropneusta with which I am acquainted can produce a vivid greenish light, from every portion of the body save the gills. When placed in a dark room during daylight hours, they do not exhibit their phosphorescence in response to mechanical stimulations of various kinds. And even at night, after they have been in darkness for some time, five minutes' illumination by the relatively feeble light from a twenty-five watt tungsten filament, placed fifteen feet from the aquarium, was found to make it more difficult to elicit the phosphorescent response. When a number of individuals were placed in the early morning in a dark-room, it was found impossible six hours later to obtain light production in response to mechanical stimulation unless the animals were strongly pressed or struck. Induction shocks of moderate strength, however, did induce light production at any time, whether the Ptychodera had been in darkness or in light.

It is clear, then, that light exercises a distinctly inhibitory effect on light production by these enteropneusta. Small fragments of the balanoglossids will, if kept in darkness, respond at night to a blow struck on the side of their container, by the emission of a bright glow. But even these isolated pieces are affected by bright light just as are the complete animals. Hence a central nervous effect is eliminated, and it is legitimate to state that light can act directly on Ptychodera (and Glossobalanus) in such a way as to inhibit the excretion of light-producing substances. I was unable to carry out an experiment which would submit one portion of a Ptychodera to light while the rest remained in darkness, and can therefore say nothing about the possible nervous transmission of this kind of photic influence.

SUMMARY

Balanoglossids are here described which are photokinetic, and orient away from the light in a machine-like manner. In addition to the orienting stimulus, it is shown that light has another, possibly separate, effect upon these animals, namely the inhibition of light production. The tip of the proboscis is the part most sensitive to illumination, but the rest of the animal's surface is likewise open to stimulation by light. The collar nervous system (delaminated part) is unnecessary for the coordinated movements of orientation, and also for the inhibitory influence of light on the production of luminescence.

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No. 73.

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NOTES ON THE LOCOMOTION OF CERTAIN BERMUDIAN MOLLUSKS[1]

J. M. D. OLMSTED

ONE FIGURE

Vlès ('07) has classified the types of gastropod locomotion according to the region of origin and method of progression of the pedal waves. He applies the term direct to those waves which pass over the foot in the direction in which the animal itself is moving, i.e., from posterior to anterior, and retrograde to those which proceed in the opposite direction. He has made a further subdivision with reference to the lateral extent of waves, calling the locomotion monotaxic when each wave extends across the whole width of the foot, di- and tetrataxic when two and four parallel systems, respectively, are exhibited on a foot. Parker ('11) found that it was possible to distinguish two subtypes in ditaxic locomotion, one in which the waves of the two sides alternated in position, and the other in which they were opposite to each other. Parker also made a further addition to the types of gastropod locomotion when he described the "arhythmic pedal movements" of Illyanassa obsoleta Say.

In the present paper further examples of several of these types are reported, as well as several new types, which present decided peculiarities A method of demonstrating that pedal waves are concavities is given, and backward locomotion is described. The work was done at the Bermuda Biological Station in the summer of 1916. I am indebted to Dr. G. H. Parker for suggesting a study of gastropod locomotion, to Dr. W. J. Crozier for his courtesy in turning over material to me, and to Dr. E. L. Mark and to the Trustees of the Humboldt Fund for having made it possible for me to go to Bermuda. My thanks are

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[1] Contributions from the Bermuda Biological Station for Research. No. 73.

also due to Mr. W. F. Clapp for the identification of the majority of the mollusks referred to in this paper.

1. The huge slug, Veronicella schivelyoe Pilsb., which, according to Verrill ('02), is not known to occur elsewhere than in Bermuda, shows direct monotaxic locomotion, i.e., the pedal waves pass from posterior to anterior and extend the full width of the foot. In Veronicella, when the animal is moving, there are always about eleven such waves, a condition which is in strong contrast to another pulmonate abundant in Bermuda, Onchidium floridanum, which shows the same type of locomotion, but shows only one or two waves at a given time. The number is fairly constant for individuals of Veronicella having very different lengths. It may even be that the number is constant for the species and that the difficulty of counting the rapidly moving waves in the small animals is responsible for the small differences obtained.

LENGTH OF FOOT	AVERAGE NUMBER OF WAVES
cm.	
14.8	11.8
9.6	11.2
9.4	11.3
8.6	11.3
7.9	10.0
3.8	10.5

These animals give an interesting reaction if they are disturbed after having once come to rest. When one taps the animal lightly, as for instance with a pencil, at any point on the posterior third of its dorsal surface, waves appear on the foot varying in number from the whole eleven in the case of a light tap, to five after a strong tap. In the former case the slug usually continues producing pedal waves and moves away, while in the latter, the most posterior waves are the most pronounced, and as they pass anteriorly they diminish in intensity, and all disappear after two or three new waves have been added to the original number. If, however, one taps the slug's head, this part is pulled back and no waves at all appear on the foot. When the animal is moving, tapping on its posterior third has no effect, unless perhaps to make it move faster, while to tap the head causes the antennae to be drawn in and the waves in the anterior half of the foot to disappear at once Künkel ('03) found a somewhat similar reaction to be given by several species of slugs of the genus Limax. If an actively creeping Limax is touched on the back or on the side of the foot, the pedal waves cease for a moment, after which the slug resumes its movement. Species of the slug Arion, on the contrary, when stimulated in the same way, cease wave movement and remain contracted for some time.

2. Eulota simularis Fer., a snail found in exactly the same habitat as Veronicella, has the same type of locomotion. I was able to count the number of waves on the foot in two specimens only.

LENGTH OF FOOT	AVERAGE NUMBER OF WAVES
cm.	
2.7	9
2.1	10

Eulota also shows similar reactions to Veronicella, for if a moving Eulota is pushed forward by a thrust on the posterior of the shell, locomotion proceeds normally and the tentacles are not drawn in; but if the animal is pushed backward by a thrust on the anterior of the shell, the pedal waves cease and the anterior end of the foot loosens its hold on the substrate.

3. Helcinia convexa Pfr., 4. Tethys dactylomela Rang. (cf. Jordan, '01), and 5. Fissurella nodosa Born show retrograde monotaxic locomotion.

6. Tectarius misricatus L. exhibits retrograde alternate ditaxic locomotion.

7. Tritonidea tincta var. bermudensis Dall affords an example of retrograde tetrataxic locomotion. The foot of this snail is a much smaller organ in proportion to the rest of the body than that of other gastropods I have examined. Its average length is 8 mm. and its width 2 mm. Running longitudinally down the center of the foot is a fine white line hardly visible unless the

animal is moving. During locomotion, a wave starts next this middle line, and is followed by another near the outer edge of the foot. Then a wave appears on the other side of the median line, and in turn is followed by a wave near the outer edge of that side. If one considers the foot as divided into quarters by lines running parallel to the long axis of the foot, and if he numbers these quarters from left to right 1, 2, 3, 4, then the waves appear in this order, 2, 1, 3, 4 or 3, 4, 2, 1.

8. Columbella mercatoria L. is also retrograde tetrataxic in its locomotion.

9. Cypraea exanthema L. exhibits a type of locomotion different from any described by Vlès ('07) or Parker ('11). Only one specimen was brought to the laboratory during the season and the following description is taken from this animal. During the first three or four days in the laboratory it moved constantly in its jar, coming to rest always on a lateral wall. Later, locomotion occurred only when it was disturbed.

The foot was somewhat pointed at the anterior end being more rounded at the posterior. The lateral edges were practically parallel. In repose the length of the foot was 8.5 cm. and the width at the anterior end 6, but when moving the foot was lengthened to about 9.5 and narrowed to 4 cm. At the extreme anterior edge of the foot (fig. 1) was a narrow (0.5 mm.) band of light, almost white tissue, which exhibited a constant rippling motion. This seemed to bear no relation to the ordinary waves appearing on other portions of the foot.[2] I made many attempts to cause the animal to attach itself to a glass plate by some region of its foot other than the extreme anterior part, but in no case was I successful. For the act of attaching, it seemed necessary that the anterior part of the foot, including the white band, be in contact with the substrate, but when the whole foot once became attached I could, by a quick shove, push the anterior three-fourths off the plate, and still the animal was able to cling perfectly with the remaining fourth of its foot. When in this position, it would bend the anterior edge of the foot around and attach it to the other side of the plate, so that its foot was

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[2] Cf. Parker's ('11) description of the locomotion of Illyanassa obsoleta.

folded over and attached to both surfaces of the glass at once. The animal would then move forward keeping the posterior part of the foot still in contact with the other side of the plate, until gradually the whole foot was on the other side. Cypraea moved with greater velocity under these circumstances than at any other time. The average rate was 1 cm. in four seconds. It was noted that the anterior 2 cm. of the foot seemed fairly free from mucus, while a large amount was secreted by the rest of the foot. It may be that the anterior edge of the foot is thus specially modified for the act of attaching the animal to the substrate by suction, and perhaps also for the reception of the stimulus which leads to the attaching reflex. This behavior is in contrast to that of Chiton and other mollusks, where any portion of the foot will become attached to a surface (Parker, '14).

Fig. 1. Cypraea exanthemia L. viewed from beneath. The animal is turning to its left. Four anterior lateral waves (dark curved areas) are moving to the animal's left, and three posterior lateral waves to its right.

But the most striking phenomenon about Cypraea's locomotion was the diversity of directions in which the pedal waves were able to proceed. As a rule the waves moved laterally, i.e., from side to side, instead of from anterior to posterior or the reverse. It was very strange to observe the whole animal moving forward while the waves which caused this movement were actually going sidewise. A single wave presented the appearance of a deep brown streak about 4 mm. wide, bounded anteriorly by a narrow (0.5 mm.) band lighter in color. When the animal was moving forward, waves made their appearance at the posterior edge of the foot, starting like ordinary direct monotaxic waves. But after each one had moved forward 0.5 to 1 cm., it suddenly bent forward, lengthened, and formed a wave which extended the full length of the foot at about 1.5 cm. from either the right or left side. If the wave extended along the left side of the foot, it then travelled to the right, keeping its front parallel to the long axis of the body with the narrow lighter band in advance. In the majority of cases the waves went from left to right, though in several instances the reverse was true. I have called such wave motion lateral, though the resulting locomotion is forward.

One could readily observe the movement of a single point on the foot, since the fine lines present could be used as landmarks. It was seen that as a wave passed over any particular point, it was carried forward, though the wave itself was moving from left to right, or right to left. Parker's ('11) scheme for gastropod locomotion can be applied in this case. The pedal wave is considered as the result of two different muscular contractions; first, contractions of "the dorsoventral muscles lift the foot locally from the substrate," and, secondly, "the contraction of the longitudinal muscles" causes "forward movement of that portion of the foot which is temporarily lifted from the substrate" and "extends the relaxing posterior fibers." But instead of these contractions taking place "in sequence from behind forward," as in Chiton tuberculatus—which exhibits retrograde locomotion—in Cypraea during lateral wave motion they must occur practically simultaneously along the whole length of the foot, the series of fibers next to contract being those at one side of the contracted ones, instead of those anterior to them. This produces the same effect as if there were single longitudinal fibers extending the whole length of the foot, each of which contracts in turn.

A second method of forward locomotion was observed in Cypraea. Waves often started from the border of the foot between the most posterior point and a point on one side some three centimeters anterior to it, and passed across the foot preserving this same alignment. This therefore made waves which, as they progressed, extended diagonally across the foot, disappearing first anteriorly. In one case while the animal was going forward, such diagonal waves which had been moving from left to right suddenly stopped, and diagonal waves started up in the opposite direction, i.e., from right to left, but without causing cessation of locomotion or a change in the direction of the animal's movement. When one watched a particular spot on the foot over which diagonal waves were passing, it was evident that the spot was carried both forward and sidewise. In this case one must suppose that another set of muscles running transversely in the foot is also in operation, and that both longitudinal and transverse muscles act simultaneously, producing locomotion in a direction demanded by the law of parallelogram of forces. It would seem therefore that the whole animal, instead of moving straight forward, was probably moving forward and to one side at the same time. The distances traveled by the animal were so short (1 to 2 cm. at a time) that I was unable to determine this accurately. If this supposition is true, a periodic reversal of direction of diagonal waves would keep the animal in an essentially straight path.

Forward locomotion, however, was seldom observed in Cypraea. Usually the animal kept turning and moving in circles, now to the right, now to the left; if to the left, waves started in the anterior third of the foot about one-half centimeter in from the right edge, and extended from the extreme anterior end backward about one-third the length of the foot. These (lateral) waves passed sidewise from right to left. At the same time lateral waves started on the left side, extending from the center of that side to the posterior end. Not only could there be two sets of waves moving in opposite directions, but in several cases three separate sets were to be seen. Once, when the animal was turning to the left, waves in the anterior third passed from right to left, in the middle third a second set passed from right to left, but at a different rate and not continuous with the anterior waves, while in the posterior third of the foot, waves were moving from left to right. At another time, when the animal was turning to the right, waves in the anterior part of the foot passed from left to right, in the middle from right to left, and in the posterior from right to left. In every instance, however, the waves in the anterior third were moving in the same direction that the whole animal moved, and in the majority of instances the waves in the posterior third passed in the opposite direction (fig. 1). This would naturally accomplish a quicker turn than any other combination, and would therefore be what one might expect to find. Several instances were, however, noted in which the posterior waves were moving in the same direction as the anterior ones.

A still further complication occurred when an antero-posterior wave appeared at the same time with the lateral waves. This retrograde wave was seen only when the animal was turning rapidly. It occurred on the inside of the curve which the foot made when bending around, i.e., if the animal was turning to the left, the retrograde wave appeared on that, the shortened, side. It was a much wider wave than any of the others, had no light area preceding the brown band, and extended as a rule only half the width of the foot. It did not seem to interfere with the lateral waves, which moved perpendicularly to it. The two waves passed over each other and neither was interrupted. One could see the lateral wave anterior and posterior to the retrograde wave, and the retrograde wave on each side of the lateral one. To this type of locomotion I have given the name composite.

Another strange condition was observed when the Cypraea was held at such an angle with a glass plate that it could attach only the very anterior end of the foot. Waves appeared spreading out in a fan-shaped manner from the center of the foot, in some cases half of them going to the right and half to the left, in other cases, all to the right or all to the left. The foot attached progressively more and more of its surface to the glass, and when two-thirds were adhering, it became evident that these waves were the ordinary lateral waves of the anterior third of the foot, and that they presented this appearance because of the contraction of the unattached portion of the foot. The interesting point was that even in a given portion of the foot waves could go both to the right and to the left at the same time.

When one pushed backward with gradually increasing force on the shell of Cypraea, the posterior third of the foot became the same light color as the narrow band which preceded the dark portion of the lateral wave, and at the same time lateral waves started in opposite directions in the anterior and middle thirds. Similar results were obtained when one pushed forward or to the right or left on the shell, a lighter colored area appearing on the side opposite to that on which the force was being applied, waves likewise being set up in the rest of the foot. Like many other mollusks, it was very difficult to dislodge Cypraea by a steady push, but this was easily accomplished by a sudden thrust.

The different forms of waves which may therefore appear on the foot of Cypraea are (1) long lateral waves, which extend the whole length of the foot and move either to the right or to the left; (2) short lateral waves, which are about one-third the length of the first, two or three sets appearing at one time, the waves in any set moving either to the right or left or half of them to the right and half to the left; (3) diagonal waves, which extend the whole distance across the foot and move either to the right or the left; (4) retrograde waves, which extend from the anterior edge of the foot to the center and, of course, run from anterior to posterior.

10. Marginella arena Val. moves much faster than any other marine mollusk that I examined. The average length of the foot is only 1.2 cm. and it moves at the average rate of 1 cm. in 2.4 seconds. No waves at all were discernable on the foot of this gastropod. The animal is so small and so slippery with mucus, that one cannot hold it in the fingers to test the foot with carmine for ciliary action. I therefore attached the shell to a

glass rod by means of "orange sticky wax" and was thus enabled to observe the effect of placing powdered carmine on the foot. The grains of carmine were caught in the mucus and rapidly conveyed posteriorly. I then teased bits of the foot and found upon microscopical examination that long and vigorously beating cilia were present all over the surface of the foot. Those along the edges seemed to beat the more vigorously. This, so far as I know, is the first example of locomotion by ciliary action alone reported for a marine gastropod.

11. The foot of Haminea antillarum Orb. also exhibited no waves This gastropod secretes a very large amount of mucus. If one draws a glass rod along the bottom of the dish across the animal's track, a centimeter or less behind the animal, it is possible to swing the animals around by means of the tough mucus thread which it has left behind itself. Carmine grains sprinkled on the foot are carried posteriorly. Microscopic examination of the teased foot showed cilia on all parts.

12. Bulla occidentalis A. Ads. also has a ciliated foot and shows no pedal waves. Bulla and Haminea move very much more slowly than Marginella. Only one specimen of Bulla was found The length of the foot was 1.3 cm. and the animal moved on an average 1 cm. in 20.9 seconds. Haminea's rate is similar.

In enumerating the types of gastropod locomotion, one should not omit the peculiar swimming motion of the 'sea-hares,' such as Aplysia limacina and Tethys dactyliomela. This is accomplished by wing-like appendages of the mantle, the parapodia. The two gastropods named can also move over a surface by means of retrograde pedal waves.

The following outline gives the relations of all the types of gastropod locomotion which have been described, with the exception of the gallop of Helix dupetithoutarsi (Carlson, '05, Jordan, '05; Parker '11).

- I. Parapodial.
- II. Pedal.
  - A. Arhythmic.
    - 1. Ciliary.
    - 2. Muscular.
  - B. Rhythmic.
    - 1. Direct.
      - a. Monotaxic. b. Ditaxic. $\left\{\begin{array}{l}\text{(1) Alternate.}\\ \text{(2) Opposite.}\end{array}\right.$ c. Tetrataxic.
    - 2. Retrograde.
      - a. Monotaxic. b. Ditaxic. c. Tetrataxic.
    - 3. Diagonal.
      - a. Monotaxic. b. Ditaxic.
    - 4. Lateral.
      - a. Monotaxic. b. Ditaxic. c. Tritaxic.
    - 5. Composite.

Parker ('14) has briefly described backward locomotion in Chiton tuberculatus. I was able to study the animal's backward locomotion in detail by allowing a Chiton to attach itself by the posterior portion of the foot to the lower edge of a glass plate held vertically in the air. The following record is typical.

Experiment Four. Chiton C. Length of foot 7 cm. Attached by 1.5 cm. of posterior end of foot to plate. Waves began at once.

1st wave carries foot 0.6 cm. up plate.
2d wave carries foot 1 cm. up plate.
3d wave carries foot 1.1 cm. up plate.
4th wave carries foot 1.1 cm. up plate.
5th wave carries foot 0.1 cm. up plate.
6th wave. Body turns and foot moves forward 0.3 cm.
7th wave. Head against plate. Rim of shell still extending beyond plate. Further turning. No forward progression.
8th wave. Whole animal against plate.
9th to 13th waves carry animal forward.

In this trial the Chiton moved straight backward a distance of 3.9 cm. in a series of five waves before it began to turn. In many specimens turning began earlier, e.g. with the second or third wave. One-fourth of the foot was the least that would become attached and remain long enough for waves to carry the whole foot up on to the plate. After a number of trials with the same individual, the animal would finally back and turn just enough to place the whole foot in contact with the plate. This is a similar result to that which Parker ('11) found with an exhausted Helix pomatia.

The ordinary pedal waves which carry Chiton forward are composed of two bands, the first lighter in color than the rest of the foot and often 1.5 cm. broad, the second following the first and darker in color, usually half a centimeter in breadth. The wave which carries Chiton backward moves in exactly the same direction as the other, i.e., is retrograde, but has no lighter portion. It consists solely of the very dark band and is about 0.7 cm. broad. It can be seen that this area is one of great contraction since it may be raised from the substrate 2 mm. or more.

For backward movement Parker's ('11) scheme holds good, the only change being that the fixed point of each longitudinal fiber during contraction is the posterior instead of the anterior end. The wave would then travel in the same direction as before, but the animal would proceed in the opposite direction.

Experiments were also undertaken to determine whether Chiton would 'back' when attached to the top and sides of a vertical plate by the posterior end of the foot. The weight of the body seemed to influence the reactions in both cases. When attached to the side, the first wave only would carry the foot in a straight horizontal direction, all the succeeding waves carried the animal diagonally, a combination of backward and turning movements. When attached to the upper edge of the plate, the Chiton would bend over and attach the anterior end of the foot to the other side of the plate if less than one-fourth of the foot was attached. But if one-fourth or more of the foot is attached, the animal will, without turning, back on to the plate, covering a distance of 1.5 cm. in 4 waves. Twelve trials were made where the individual was balanced across the upper edge of the plate and allowed to attach as it would. Five times it attached the anterior end of the foot and moved forward, seven times the posterior end was attached and the animal backed down the glass. In nearly every trial the Chiton would raise its anterior end and thus upset the balance, causing the posterior end of the foot to touch the plate. Nevertheless in nearly half the trials contact with the plate did not cause the posterior end to become attached.

The only other mollusk I was able to cause to move backward was the keyhole limpet Fissurella. When the posterior fourth or more of its foot was attached to the lower edge of a vertical glass plate, the head of the animal being directed downward, the first wave or two would carry the limpet straight backward for a distance of 2 millimeters or more, then turning would take place. Here again the direction of the wave which carried the animal backward was the same as that which carried it forward. All other mollusks tried were so flexible or had such a large foot that they would bend over and attach the anterior part of the foot to the other side of the glass. Naturally conditions under which these experiments were conducted would hardly be realized in nature. Backward locomotion is probably seldom resorted to by gastropods, at least for any considerable distance, since turning took place sooner or later in every trial. Nevertheless certain mollusks possess the ability to perform such movements.

A clear demonstration that pedal waves are concavities and not convexities (Biedermann, '05; von Uexküll, '09; Parker, '11) is afforded by the use of a manometer. A hole 1 mm. in diameter was bored in a glass plate. Under this was fastened by an air-tight joint of "orange sticky wax" one end of a capillary tube which was bent back on itself in two places forming a letter 's'. The tube was marked off in millimeters and a colored solution was introduced so that any change in level could be readily detected. This capillary manometer was used by placing a mollusk on the underside of the plate and watching the liquid as the animal passed over the hole. For every gastropod tried—Cypraea, Veronicella, Onchidium, Tectarius, Fissurella, Eulota, and also Chiton—the liquid was drawn toward the animal just as a wave passed over the opening in the plate, and then returned to its former level immediately after the wave had passed. This shows that the wave exerts a suction and must therefore be a concavity. The Chiton foot seemed to give the greatest amount of suction of all the mollusks tried, a difference in level of 3 to 4 mm. being observable. In all other cases a difference of at least 1 mm. could be seen with the exception of Eulota where the waves passed in such rapid succession that only a slight movement of the liquid could be detected.

SUMMARY

1. Three types of locomotion may be added to Vlès ('07) and Parker's ('11) classifications of gastropod locomotion, viz. (1) lateral, (2) diagonal, and (3) composite.
2. Cilia are the means of pedal locomotion in Marginella, Haminea, and Bulla.
3. Chiton and Fissurella are able to move backward without reversing the normal direction of their pedal waves.
4. Pedal waves can be shown by the use of a manometer to be areas of suction and therefore concavities.

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No. 74.

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THE COMPARATIVE PHYSIOLOGY OF SYNAPTULA HYDRIFORMIS (LESUEUR)[1]

J. M. D. OLMSTED

TWO FIGURES

CONTENTS

INTRODUCTION

Two varieties of Synaptula hydriformis (Lesueur), red and green, are found at Bermuda in approximately equal numbers. All gradations between these two colors are present, and there are

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[1] Contributions from the Bermuda Biological Station for Research. No. 74

many quite transparent individuals of a very pale flesh color which appear light green when placed on green sea-weed, and a light red on red sea-weed. Clark ('07) reports that he found synaptulas more abundant on green Ulvaceae, but I collected comparatively few specimens from green sea-weed, obtaining them almost exclusively from red algae growing in shallow water on broad sheltered flats (Millbrook Creek). There was absolutely no 'outspoken mimicry' of the environment by the animal such as Semon ('87, p. 280) describes for several species, since both red and green synaptulas occur on both red sea-weeds and green ones. Dr. W. J. Crozier informs me that he has found this species in August on the outer reefs in the brown Sargassum, and that the red and green varieties were present there in equal numbers. In my collecting, by far the greater number were taken at the base of clumps of red sea-weed, where a slate color or even black prevailed (Clark, '98, p. 56).

The work was done at the Bermuda Biological Station for Research during the summer of 1916. I wish to thank the trustees of the Humboldt Fund and Dr. E. L. Mark for making it possible for me to go to Bermuda, and also Dr. W. J. Crozier for suggesting this species to work upon. Further acknowledgment is due Dr. Mark for his helpful criticism of the manuscript.

I. GENERAL PHYSIOLOGY

1. Locomotion

Locomotion through sea-weed is accomplished largely by means of the tentacles, though movements of the body in the form of peristaltic waves assist. That the tentacles subserve locomotion, as well as the sense of touch, in holothurians was first shown by Tiedemann (1816). The locomotor function is so emphasized in this particular species that Lesueur ('24) in his original description of the species says: "In locomotion the tentacles are used as feet." It is interesting to note that the second time this species is mentioned, this characteristic is again referred to, for "there can be no doubt that Pourtalés' ('51) Synapta from Biscayne Bay, which he called viridis, is identical with Lesueur's and Oersted's West Indian species" (Clark, '07, p. 83). Pourtalés reports that when specimens of this species were placed in a glass jar, they would climb along the sides of the vessel by means of their tentacles, their bodies hanging down in the water, and they seemed to adhere to the glass by the outside surface of their tentacles.

The body movements are much like those of the earthworm. Indeed, the arrangement of the muscles is the same in both animals; circular muscles lie just beneath the epidermis, and longitudinal muscles internal to the circular ones. At one phase of the movement the circular muscles contract and the body of the Synaptula is elongated. This is succeeded by a contraction of the longitudinal muscles,—following von Uexküll's ('00) rule whereby the stretched muscle is the next to contract,—which shortens the body. Instead of setae, Synaptula has calcareous anchors, which serve as fulcra when the animal is moving, or as very efficient hold-fasts when one attempts to remove a specimen from sea-weed. Concerning the function of these peculiar structures, which have their origin in the dermis, Selenka ('67) ventured to suggest that they grew out beyond the subcuticula, bored through the thin membranous outer skin, and aided the Synaptula in clinging to the substrate. Semper ('68) on the contrary, claimed that "ein solches Durchboren findet aber nie in natürlichen Zuständen statt," and he suggested a totally different function, i.e., that of 'Tastorgane.' Nevertheless the anchors do project beyond the epidermis and render it almost impossible to remove a Synaptula from sea-weed without injury. In collecting specimens, it was found best to break off a bit of sea-weed with an animal clinging to it, rather than to attempt to pull the animal away from the sea-weed. They even cling to one's finger so that it is with difficulty that they can be shaken off.

Naturally anchors are of no avail when the animal is creeping up the vertical surface of a smooth glass vessel. In this case the whole outer glandular portion of the tentacles (cf. Pourtalés, '51), not merely the tips as in Rhabdomolgus ruber (Becher, '07, p. 554), adheres to the surface along which the Synaptula is moving. The longitudinal muscles of the tentacles contract, thus pulling the body forwards, and immediately another tentacle is attached above the first. There is no twisting of the tentacles such as Clark ('99) describes for Synapta inhaerens and S. roseola. The adhesion to the glass is so strong that a tentacle presents the appearance of being almost torn away when it finally lets go. The effectiveness of the pull of any tentacle ceases when another tentacle, attached higher than the first, begins in its turn to contract and pull the body up, yet an attached tentacle seldom loosens its hold until it has assumed an 's' shape, the proximal end having reached the same level as the distal end. This is what one would expect if the tentacles were attached to the glass merely by some adhesive substance and not by muscular action. If there were actual suction, such as that by which a mollusk clings to the substrate, circular, or possibly radial, muscles would be required to lift a portion of the tentacle away from the surface to create suction, and in that case release would probably occur as soon as the pull on the tentacle ceased. This is exactly the point which, I think, makes Semon's ('87, p. 283) explanation wrong. He thinks that "die Anheftung geschieht, indem hierdurch beim Nachlassen des Druckes an verschiedenen Stellen zwischen Glaswand und der unebenen elastischen Haut der Tentakel leere Räume oder weningstens Räume entstehen, in denen das Wasser sich unter geringerem Druck befindet als das umgebende Medium." Since the tentacles remain attached after they cease to be effective in pulling the animal forward, and have to be fairly torn away from their attachment, it seems probable that muscular action plays no part in the adhesion of a tentacle to a surface. This is in accord with the results of anatomical investigations, namely that longitudinal muscles are in all probability the only muscles present in the tentacles (Clark, '07, p. 45). Synaptulas will hang so firmly attached to the wall of a dish that they can be shaken and the water quite severely agitated before they will loosen their hold. A Synaptula 4 cm. long can crawl up a vertical glass wall carrying in sea-water a piece of iron weighing 30 mgm. in air (ca. 26 mgm. in sea-water) tied to its posterior end.

The peristaltic waves, which assist locomotion through the sea-weed, occur at irregular intervals, having no rhythmic sequence. Each wave starts at the posterior end of the body as a marked constriction some 2 to 3 mm. wide. The constriction passes anteriorly taking about 15 seconds to complete its course in a Synaptula 45 mm. long. This rate, about 3 mm. per second, is by no means constant, since in a given specimen waves were found to take 18 seconds at one time and 16.6 at another. Waves appear when a Synaptula is moving along a horizontal surface, but not when it is crawling up a vertical wall. They also occur when the animal is defecating. A fairly light mechanical stimulus, such as a touch with a glass rod, causes a local constriction, which often initiates a peristaltic wave if the stimulus is applied to the middle region of the body, but not if applied to the extreme anterior or posterior end. Similarly, local application of various chemicals, such as KCl, NaCl, acetic acid, etc., calls forth constrictions which may initiate a wave if applied to the middle regions of the body. Peristalsis also occurs under the following conditions: when the animals are fed carmine powder; when they are returned to water at 27°C. (the normal) after having been immersed for 3 minutes in sea-water at higher temperatures; when they are placed in calcium-free sea-water.

Since peristalsis appears under such diverse conditions, it is probable that this is a general response given to many kinds of stimuli. At first it was imagined that only excessive stimulation might provoke peristalsis; but this was found not to be the case, since moderate stimuli, either mechanical or chemical, applied to the middle region of the body, nearly always produced this response. It is probably the mechanical stimulation, due to contact, which causes peristalsis when the animal is lying on a horizontal surface or among sea-weeds.

In two instances reversal of direction of the wave was noted. In both cases several peristaltic waves passed completely from the anterior to the posterior end immediately after cutting off the head by a single stroke of the scissors.

When moving through sea-weed the animals often curl the last 5 mm. of the body about a branch and explore their surroundings in all directions. If some twenty or more individuals are placed in a finger-bowl, they at first cling together in a dense wriggling mass. Presently they begin to separate. The tentacles attach to the bottom, then to the sides of the dish, but their posterior ends remain hooked into one another. The tentacles then carry the oral ends up to the top of the water, the posterior ends still holding to one an other, until the mass of animals is spread out in a sheet, each individual like a spoke in a wheel. This would seem to indicate a positive reaction to mechanical stimuli at the posterior end of the animal, yet in trials in which this portion was gently touched with a blunt needle, only negative reactions were given.

Although holothurians exhibit the usual radial symmetry common to all echinoderms, they are decidedly more bilateral than other classes of the phylum. The surfaces to which are attached mesenteries that hold the intestine in place, are called dorsal and ventral. The only author who shows that this bilateralsymmetry in the apodous holothurians is connected with their behavior is Semon ('87). He found that Synapta digitata and S. hispida normally creep with one side, the dorsal, uppermost. In Synaptula hydriformis, likewise, there is a tendency to keep one side away from the substrate. This surface is decidedly darker and contains more miliary granules than the opposite one. Clark ('98) found no such difference in specimens of this species which he obtained in Jamaica, but it is certainly very pronounced in those of Bermuda. If a Synaptula which is moving horizontally along the bottom of a dish is gently turned over so that the lighter colored side is uppermost, the animal may draw in the tentacles completely, contract the body, roll slightly to the right or left, and then move on again with the dark side up. Usually, however, the animal, when turned over, continues locomotion using the tentacles of the lighter side to pull itself along, rolling over gradually until the dark side again appears uppermost. The average time required for a Synaptula to right itself in this way was 45 seconds. In ordinary undisturbed locomotion a few cases were noted where an individual rotated on its long axis, but this was by no means the usual procedure, either when crawling up the side of a vessel or along the bottom. When a Synaptula, in creeping up a vertical wall, reached the surface of the water, it generally began moving horizontally, say to the left, attaching its tentacles more or less in regular sequence, and rolling over, till the lighter side of its body was away from the wall. Then, instead of making a complete revolution and continuing to the left, it would 'roll' back to its starting-point and over to the right, until again the lighter side appeared. It would thus roll back and forth some five or six times before it finally loosened hold and dropped to the bottom. Similarly, while crawling along the bottom of a dish, a Synaptula usually rolls back and forth, very seldom moving in a spiral.

Upon dissection this lighter colored side, the one which is kept next the substrate, was found to be that which, for morphological reasons, has been called ventral. Aside from the difference in color and in abundance of miliary granules, differences which are evident in both red and green varieties, there are no external differences between dorsal and ventral surfaces.

The Holothuria can be arranged in a series according to increasingly pronounced bilateral symmetry and physiological polarization. One of the lowest members of such a series is Thyone briareus, which has tube-feet along all five of its antimeres, and moves with any side forward (Pearse, '08; Mast, '11, p. 211). Holothuria surinamensis and H. rathbuni, according to Crozier ('14 a, '14 b), are intermediate forms, while Holothuria captiva occupies the upper end of the series, since it has tube-feet on the ventral side ('trivium') only and always moves with the oral end forwards (Crozier, '14 b). Synaptula hydriformis would rank with Holothuria captiva, since, although its bilateral symmetry is not so pronounced, its physiological polarity is most marked.

2. *Feeding and digestive movements*

In spite of the fact that this Synaptula moves with one particular side next the substrate, its rolling motion brings all the tentacles into play, even those on the dorsal surface. In its natural habitat in sea-weed, all the tentacles are used in locomotion at the same time, while in a finger-bowl at any given moment the majority of the tentacles wave freely in the water, two or three are attached to the surface, and two or three have been drawn down into the mouth. The animal never remains motionless, but continually moves about, first attaching its tentacles, and then after they are detached, drawing them down into the mouth as if to wipe off particles which might be attached to them. These wiping movements appear to be feeding movements, yet they occur even when no food seems to be present. For this reason Becher ('07) considered them automatic. Quatrefages ('42) found that his Synapta duvernea would swallow grains of sand when they were brought to the mouth on the tentacles. Under no circumstances was I able to see particles of any sort transferred from the tentacles to the mouth, though in several experiments carmine grains were caught upon them.

When carmine powder is dropped on the tentacles, they are at once drawn back out of sight into the mouth region, the whole body contracts, and peristaltic waves pass from posterior to anterior. The following observations on one specimen illustrate this behavior.

July 21. Specimen 4. Collected this morning. Length 4.5 cm.

3.53 p.m. Animal on bottom of dish. Carmine suddenly squirted into mouth. Draws in tentacles. Shortens body. Three peristaltic waves.
3.55 p.m. Defecates. Three more waves. Climbs to top of dish.
3.57 p.m. Drops to bottom. Draws in tentacles. Climbs up.
4.00 p.m. Several peristaltic waves.
4.01 p.m. Drops to bottom. Two peristaltic waves. Climbs up again.
4.05 p.m. Defecates.
4.08 p.m. More waves. Drops to bottom.

This is in strong contrast to the ordinary behavior, for a Synaptula usually remains at the top of the dish for some 10 or 15 minutes without dropping, and no peristaltic waves are to be seen.

If carmine in sea-water is quickly squirted into the mouth while the tentacles are extended, the red grains appear later in the intestine, and finally come out in the castings. In fourteen animals, each about 6 cm. long, carmine appeared in the castings after an interval averaging 20 hours, and varying from 18 hours in one case to 21 hours in five cases. This means that, unless carmine has an accelerating effect, it takes about 21 hours for the food to pass from the mouth to the anus.

In freshly collected synaptulas one can always see faeces in the intestine at a distance from its anterior end slightly less than half the length of the intestine. The castings are cylindrical masses about 3 mm. long and 0.5 mm. in diameter, and are yellowish white. Often there are two or three attached end to end. Since there are regular rhythmic movements in the whole intestine, there may be some mechanism which determines the form of these castings similar to that of Stichopus (Crozier, '16a). Clark ('98, p. 56) states that in specimens from Jamaica "the food consists largely of vegetable matter, diatoms being present in the stomach." Microscopic examination of the contents of the intestine and the faeces of Bermuda specimens failed to show the presence of diatoms, but the empty walls of a small filamentous (red?) alga were abundant. The chromatophores of the alga and all parts inside the cell walls had disappeared in the course of digestion. This difference in food between specimens from Jamaica and from Bermuda is probably due to the greater abundance of diatoms in the West Indies.

The intestine of Synaptula shows strongly marked peristaltic waves, which travel from the anterior to the posterior end, a direction opposite to that of the irregularly occurring waves of the body-wall. Since the animal is in constant motion and the integument in most cases is not sufficiently transparent, attempts to time these waves in the normally active animal were not successful, but the average rate of pulsation in the intestine of a Synaptula which was held upon a glass slide by weights and whose body-wall was slit so as to disclose the intestine was ten waves in 19 seconds at 27°C. The average rate of pulsation in the intestine after its removal from the body was ten waves in 28 seconds at the same temperature.

The excised intestines assume a constant rate of pulsation within 5 minutes after operation. In two cases, when they were allowed to remain undisturbed, they were found to be pulsating regularly at the end of 7 hours, though much more feebly than when first dissected out (table 1).

TABLE 1

Synaptula intestine in sea-water at 27° C.

TIME	TIME ELAPSED	RATE: TIME REQUIRED FOR 10 BEATS
10.35 a.m.	Operated	
10.41 a.m.	6 minutes	28 seconds
12.15 p.m.	1 hour 40 minutes	31 seconds
12.45 p.m.	2 hours 10 minutes	30 seconds
3.15 p.m.	4 hours 40 minutes	30 seconds
5.15 p.m.	6 hours 40 minutes	30 seconds

a. Effect of change of temperature on intestinal pulsation. The effect of change of temperature on living material has shown than van't Hoff's, or the R. G. T., rule holds good in the organic as in the inorganic world (Pütter, '14). The intestine of Synaptula is no exception. The curves in figures 1 and 2, which show the effect of change of temperature on the rate of pulsation, are typical. Q_{10} is found to have the following values:

$$16°\text{–}21° = 3.24$$
$$21°\text{–}26° = 2.56$$
$$26°\text{–}36° = 1.4$$

These values for Q_{10} are of the order of magnitude of those for chemical processes, as Crozier ('16 a) found for the rhythmic pulsation of the cloaca of certain holothurians. This series also shows the phenomenon to which Snyder ('11) has called attention, viz., Q_{10} is greater for lower than for higher temperatures.

b. Effect of chemicals on intestinal pulsation. The effect of chemical agents on rhythmic pulsation has been the subject of considerable investigation (see Crozier, '16 a, for literature). The following experiments on the intestine of Synaptula give results which are similar to those obtained by Crozier for Holothuria.

The average time for ten beats in artificial sea-water (Mayer, '11, '14), i.e., $\frac{5}{8}M$ (100 $NaCl$ + 7.8 $MgCl_2$ + 3.8 $MgSO_4$ + 2.2 KCl + 2.5 $CaCl_2$) at 27°C. was 29 seconds. This is practically the same rate as in natural sea-water. Pieces of intestine in the artificial sea-water continued to beat regularly for seven hours, as long as the experiment was continued.

Immersion in $\frac{5}{8}M$ NaCl immediately caused a severe contraction throughout the entire length of the intestine. However, peristalsis returned in a very few seconds, and was much more pronounced than in normal sea-water. It then gradually be-

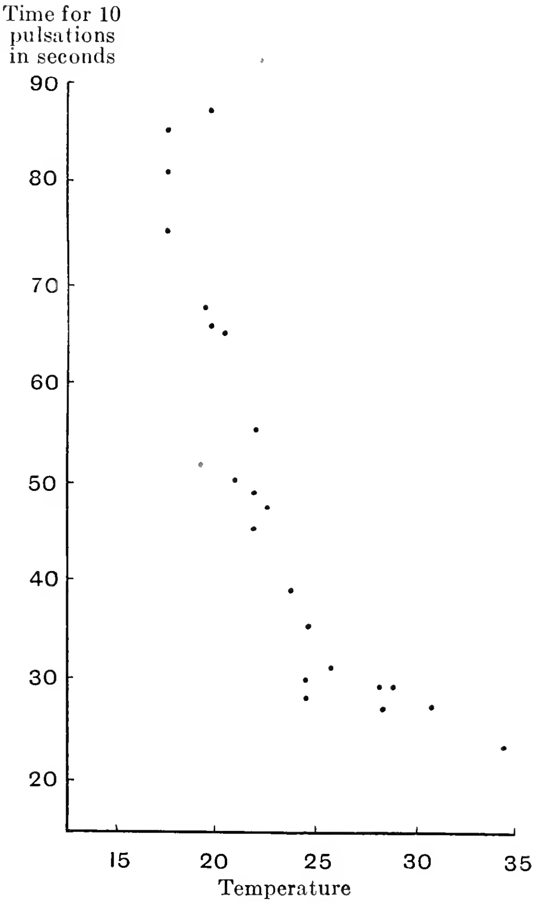

Fig. 1 Ordinates indicate time, in seconds, for 10 pulsations of an excised piece of intestine of Synaptula; abcissae indicate temperature, Centigrade. Readings taken on a single specimen.

came feebler and finally (after three minutes) ceased. When the animal was returned to normal sea-water pulsation was not resumed.

$\frac{5}{8}M$ KCl also caused the intestine to contract greatly. No pulsations at all could be detected, nor did it resume pulsation when returned to normal sea-water.

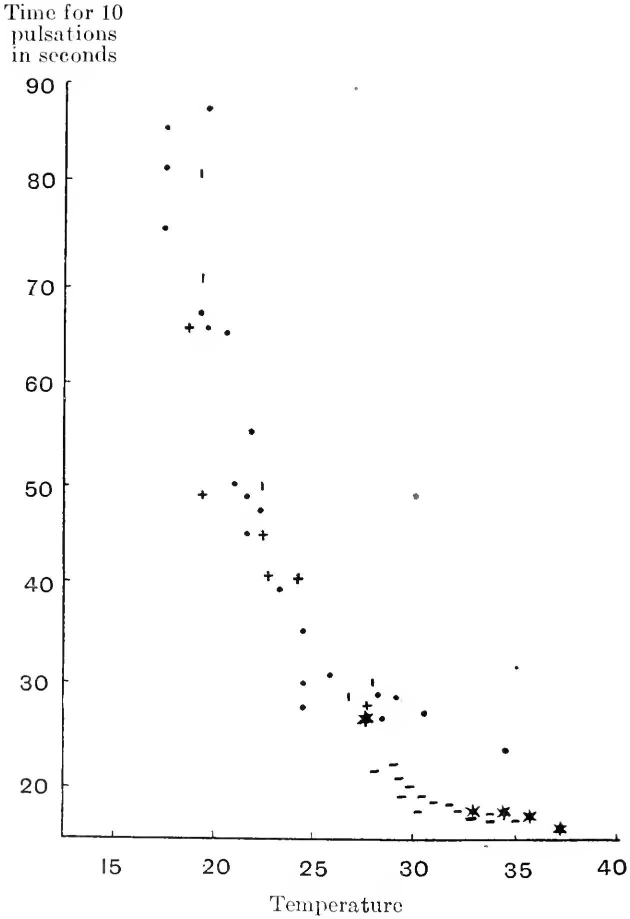

Fig. 2 Ordinates indicate time, in seconds, for 10 pulsations of excised pieces of intestine of Synaptula; abcissae indicate temperature, centigrade. Different symbols indicate different individuals from which the pieces of intestine were taken.

The same effect was observed with $\frac{3}{8}M$ $CaCl_2$, with $MgSO_4$ and with $MgCl_2$.

In calcium-free sea-water, the intestine writhed and twisted so violently that it was impossible for nearly a minute to count the pulsations. It then became quieter, and also rather opaque, though it beat at its regular rate for at least 45 minutes. After this it twitched irregularly, and finally after about one hour all movement ceased.

The only single component of sea-water, therefore, in which pulsation continues at all is NaCl, and even here pulsation ceases in a very few minutes after immersion in such a solution. NaCl + KCl + $CaCl_2$ forms a more 'balanced' solution than NaCl + KCl + $MgCl_2$ + $MgSO_4$, since regular pulsation continues in the former mixture for nearly an hour, but ceases in the latter in some 2 minutes. These results are in perfect accord with those obtained in the study of the cloaca of Holothuria by Crozier ('16 a).

There are no histological studies of Synapta in which nerves or nerve cells have been shown to be present in the intestine. Its behavior, however, strongly suggests the presence of a nerve net.

3. The effects of external stimulation

Synaptula, like the majority of the lower animals, exhibits but few types of reactions. To nearly every external stimulus applied to the body-wall it responds by a local constriction at the point stimulated, or if the stimulus is of sufficient strength, by a shortening of the whole body. The local constrictions are brought about by the contraction of the circular muscles of the regions stimulated and are called forth by such stimuli as touch, light, and chemical agents. If the stimulus is sufficiently vigorous, the constriction may be very deep and initiate a peristaltic wave which moves toward the anterior end of the body. The shortening of the body is, of course, brought about by the contraction of the longitudinal muscles. The antagonistic action of these two sets of muscles and their components in different regions of the body determines, of course temporarily, the shape of the animal. For example, in the contracted state of all the longitudinal muscles the diameter of the animal may be twice what it is when those muscles are relaxed; the contraction of the longitudinal muscles of one side may produce a curving of the body to that side, either throughout its entire length, or more locally, according to the extent to which the contraction affects the muscles of that side; the contraction of all the circular muscles may produce an extreme elongation of the animal; or, finally, local contraction of circular muscles may produce annular constrictions (a very common condition of all Synaptidae) at irregular intervals.

Stimulation of the very posterior end often causes, in addition to local constriction, a bending away from the source of stimulation, a reaction in which the longitudinal muscles along one side of the body come into play; or the body may be slightly shortened, in which all the longitudinal muscles of the posterior half of the animal are equally contracted. The former reaction is much the more common.

But the most striking reaction which Synaptula exhibits is the sudden withdrawal of all the tentacles into the mouth region. This occurs when a moderate stimulus is applied to any of the regions at the anterior end of the animal, e.g., the tentacles, the mouth disc, or the area which extends from the base of the tentacles backward 2 or 3 mm. This sudden turning 'outside in' is the result of very severe contraction of the circular muscles of the head region followed by that of the longitudinal muscles. The contraction of the circular muscles of the head region naturally drives the body fluid backward. When the longitudinal muscles, which are attached to the calcareous ring just below the tentacles, strongly contract they draw the ring, together with the whole head region, back into the body, until the pressure of the body fluid prevents further involution. The posterior ends of animals which have been decapitated present a plump appearance, since the circular muscles for a distance of some 3 mm. back of the cut remain strongly contracted, both closing the wound opening, and forcing the body fluid into the posterior end. A withdrawal of the tentacles is seldom shown unless the anterior end is stimulated.

4. *Other muscular activities*

a. Blood vessels. Microscopic examination failed to show any movement in the walls of the dorsal and ventral blood vessels. As Clark ('07, p. 63) states, the blood is moved by the contractions of the muscles in the wall of the alimentary canal. One can see the cells which lie in the lumen of the blood vessel shift back and forth as a peristaltic wave passes down the intestine.

b. The gonads. The gonads, however, as Clark ('98, p. 58) also observed, possess the power of independent movement. These movements consist of irregular twitchings, and last for some 30 minutes after removal from the body. Histological study has shown the presence of muscle fibers in these 'genital tubes' (Clark, '07, p. 59).

5. *Bacterial parasites*

Clark ('98, p. 56) found 'no internal parasites' in the synaptulas which he collected at Jamaica. In nearly every one taken at Bermuda there were one to four dark brown or green, almost black, spherical masses, ranging in size from mere specks to 1.5 mm. in diameter. These spheres always lay free in the body-cavity and shifted back and forth with the movements of the animal. When these bodies were crushed and examined under the microscope, they were found to consist of bacteria belonging to the genus Microcystus.

Experiments on sensory reaction of this Synaptula were conducted on both red and green varieties, but upon comparing records of the animals of the two colors, no difference whatsoever could be found between the behavior.

Summary of Part I

1. There is no mimicry of its environment by Synaptula hydriformis.
2. Attachment of the tentacles is probably by an adhesive secretion alone, not by suction.

3. Synaptula hydriformis shows decided physiological polarization, since it always moves with the anterior end foremost, and keeps its dorsal side uppermost.

4. Carmine powder fed to specimens 6 cm. in length appears in the foeces after about 20 hours.

5. The food of Bermuda specimens consists chiefly of a filamentous (red?) alga.

6. The temperture coefficient for the rhythmic pulsation of the intestine obeys the R. G. T. rule.

7. The intestine beats normally in artificial sea-water, and for a much longer time in a balanced solution of Na, K and Ca salts than in any other combination of the components of sea-water. NaCl is the only single component of sea-water in which peristaltic movement of the intestine continues at all.

8. Nearly every Bermuda specimen contains a mass of symbiotic bacteria lying free in the body-cavity.

9. The red and green varieties show no difference in their sensory reactions.

II. SENSORY PHYSIOLOGY

1. The effect of deforming pressure

a. Historical. The so-called 'touch-papillae' or 'sense-buds' are found in abundance on the tentacles of Synaptula hydriformis, but they are scattered over the surface of the body as well. Clark ('07, pp. 47, 48) describes them as "small groups of epithelial cells connected at their inner ends with special ganglia situated at the ends of small nerves, which arise as branches of either the radial or tentacle nerves." "The senory cells are much more elongated than the ordinary epithelial cells, and the inner end is drawn out into a fiber which connects directly with the small ganglion lying underneath the sense-bud." Retzius ('06), who made a study of the sensory cells of Synapta Buskii, finds the same structure and distribution of the sensory cells in this species. Semper ('68, p. 28, p. 153)—not Hamann ('83), as stated by Clark ('98)—seems to have been the first to describe such papillae in Synaptidae, and to suggest that they were

'Tastpapillen.' "Die Lage dieser Papillen macht es wohl ziemlich unmöglich in ihnen etwas anders als Tastorgane zu vermuthen." Semper also tried to show that the calcareous bodies in the dermis of synaptids, especially the anchors, serve as 'touch-organs.' He even compared them to the 'Tasthaare' of the cat. Unfortunately for his idea, he was forced to confess "Bei den Synaptiden . . . . ist es mir nie gelungen Nerven bis an die Anker heran verfolgen zu können." Semon ('87) found, as did Quatrefages ('42), that Synapta inhaerens could be somewhat roughly rubbed on the skin without eliciting any response from the animal. Since, in addition, chloral hydrate applied to the skin caused a contraction and moving away of the part stimulated, he suggested that the 'touch-papillae' were not entirely composed of touch cells, but contained also gustatory cells. Moreover, since pigment was to be found in these 'touch-papillae,' he thought that some of the cells might serve to receive photic stimuli. Practically all other investigators, however, have been content to ascribe simply a tactile function to these organs.

b. Observational. The order of diminishing sensitivity to touch in the different body regions of many of the lower animals is anterior, posterior, middle (Parker, '08; Crozier, '14 a). This order holds for Synaptula hydriformis, where the sequence is tentacles, anterior part of the body, posterior part, middle. Table 2 gives a series of reactions obtained by touching the different parts of the body with the blunt end of a needle when the animal was moving back and forth just beneath the surface of the sea-water in a finger-bowl. Similar reactions, though much more variable, were given if the animal was stimulated while moving along the bottom of the dish. In most cases a less vigorous stimulus was required to cause complete withdrawal of the tentacles when the Synaptula was at the bottom than when it was near the top of the water.

Of these reactions the only one which can clearly be called positive is the response of the outer surface on the tentacle to a very slight touch. This positive thigmotropism is probably the chief cause of the constant motion of the tentacles. The free tentacles are continully attempting to attach themselves, and

TABLE 2

Responses of Synaptula to touch: stimulus applied to various parts of the animal

STIMULUS	OUTER SURFACE OF SINGLE TENTACLE	INNER SURFACE OF SINGLE TENTACLE	MID-BODY	POSTERIOR END
1. Weak	Adheres to rod	Waves tentacle	None	None
2. Stronger than 1	Tentacle contracts and bends into mouth	Tentacle contracts and bends into mouth	Slight local constriction	Local constriction, bends away
3. Stronger than 2	All tentacles contract, half drawn into mouth	All tentacles contract, half drawn into mouth	Deeper local constriction with wave moving anteriorly	Local constriction and lashing of posterior end
4. Stronger than 3	All tentacles drawn into mouth. Drops to bottom	All tentacles drawn into mouth. Drops to bottom	Very deep constriction. Posterior half of body squirms	Local constriction with shortening of whole body
5. Very strong, (stronger than 4)	Same as for 4	Same as for 4	Drops to bottom with tentacles half drawn in	Drops to bottom with tentacles half drawn in

when once attached they remain so until fairly torn away by the attachment and contraction of other tentacles. The same reaction may also be concerned in food taking. One can readily see the value of this movement should an edible particle come in contact with the tentacle, since further movement toward the object would more surely bring the morsel into contact with the adhesive secretion on the outer surface of the tentacle, whereby a subsequent wiping motion might deliver it to the mouth.

In the reaction to the stimulus applied to the inner surface of the tentacle there is possibly another adaptive movement. The waving of the tentacle after its contact with an edible particle is likely to bring the outer adhesive portion into contact with the object, which might thus be captured and carried to the mouth.

All other reactions are clearly negative, varying in degree of completeness with the strength of the stimulus.

It seems very probable that the touch papillae do have the function of 'tangoreceptors,' but whether they are exclusively such is debatable. Their distribution corresponds with the order of sensitivity, since they are especially abundant on the tentacles and appear to be less numerous on the mid-body than on the posterior end.

Water currents directed on various parts of the body gave results such as those shown in table 3. The method of making the tests was as follows. A pipette bent at right angles was held in a vertical position with its horizontal outlet at a level with the portion of the body to be tested. Water having been drawn up into the pipette to a given height and held there by keeping the finger over the upper opening, the lower end of the pipette was then placed about 2 mm. from the region of the body to be stimulated and the finger suddenly lifted from the pipette. In this way practical uniformity in the strength of the stimuli was secured.

Individuals varied greatly in their responses to water currents. In general, a current from a column 4 cm. high produced no effect on the tentacles or head end. On the mid-body it caused shortening of the body, and on the posterior end shortening of the body with local contractions in addition. A slightly stronger

TABLE 3

Effect of water currents on Synaptula

CURRENT	ON TENTACLES	ON HEAD	ON MID-BODY	ON POSTERIOR END
Weak, column 4 cms.	None	None	Shortens body	Shortens body
Stronger, column 8 cms.	Shortens body	Shortens body	Shortens body	Shortens body
Very strong, water blown through pipette	Partly closes tentacles and drops to bottom	Partly closes tentacles and drops to bottom	Shortens body	Shortens body

current on the tentacles caused shortening of the body only, while a still stronger current caused, in addition to this reaction, a partial withdrawal of the tentacles and consequent dropping to the bottom of the dish. Stronger currents on the mid-body or the posterior end called forth the same reactions as the weaker currents, though more pronounced. When an individual was crawling along the bottom of the dish, no response to any ordinary current was shown, no matter what portion of the body received the stream.

In these experiments with water currents, the tentacles seem to behave contrary to the general rule, since they appear to be less sensitive than the other parts of the body. But this becomes intelligible when one considers that the constant motion of the tentacles must have the same effect as gentle currents impinging on them, and must also cause small currents to continually move over the anterior end of the animal, while the other parts of the body are not subjected to these currents. Once the threshold of stimulation is reached, there is a much more vigorous and complete reaction to a strong current on the tentacles than on other parts, a fact which brings these results into line with the effects of other mechanical agents.

2. *The effect of gravity and of vibrations*

a. Historical. Experiments like those of Kreidl ('93) on Palaemon have shown that those structures which earlier investigators called 'otocysts,' to which we now apply the term 'statocyst,' are, in many of the invertebrates, organs of orientation, since they react to the force of gravity and serve to keep the animal in equilibrium. Reasoning from the well established cases, it is only natural to infer that similar structures, when found in other animals, must serve the same purpose. Such structures have been described in synaptids by Johannes Müller ('50b, p. 226), Baur ('64, p. 46), and others. Hamann ('84, p. 25) considered them larval structures only, and therefore functionless in the adult. They were, however, given the name 'Gehörbläschen,' which implies their relation to the vertebrate organ of hearing.

But the latter organ is concerned with two functions, hearing and maintenance of equilibrium. Quatrefages ('42) could find nothing like audition in Synapta inhaerens, and Semon ('87) reported that the synaptids which he examined were 'tone-deaf.' Nevertheless Semon thought it probable that the 'Baur'schen Hörbläschen,' or otocysts, were for the perception of other kinds of vibrations, since the animals were very sensitive to shaking (Erschütterungen). Ludwig und Barthels ('91) agree with Semon that the "Hörbläschen auch an den erwachsenen Thieren als Sinnesorgane functionieren," though they give no grounds for their belief.

Clark ('98) suggested that in Synapta vivipara (Synaptula hydriformis) the "otocysts do not function as hearing organs at all, but are of use to indicate the animal's position." He describes these organs as ten in number, "lying external to the radial nerves at the point where they bend backwards over the calcareous ring." They are sacs 60 to 70 μ in diameter, filled with fluid in which floats or lies a 'cell' which may act as an otolith. In a second paper Clark ('99) records important observations on these organs in Synapta inhaerens and S. roseola, which he studied in the living condition under the microscope. The structure of the otocyst is the same in these species as in Synaptula hydriformis. The otolith changes its position when the position of the otocyst is changed. The makeup of the organ and the behavior of the enclosed otolith are in perfect accord with the requirements of a 'positional organ,' i.e., a surface in intimate connection with nerves on one side, and on the other with a body which changes its relation to that surface whenever the whole structure is moved. But the experiments which Clark performed show merely that his synaptids were affected by change of position. The conclusion that it was the "positional organs" which determined this behavior is an inference only.

Becher ('09) described similar 'Hörbläschen' in Leptosynaptula bergensis, and found that they, too, meet the requirements of a 'statocyst.' He also tried tones, and vibrations of lower frequencies, but could observe no response. His statement

"Mit Sicherheit können wir annehmen, dass die Synapten die Stellung ihres Körpers mittels der Statozysten wahrzunehmen imstande sind" is, as Buddenbrock ('12) points out, mere speculation, since there is no experimental evidence to prove it. As to Becher's theory of the action of the statocyst, Buddenbrock insists that it is "nicht gut fundiert" and "in die Kategorie der völlig unkontrollierbaren Spekulationen gehört." From his own experiments Buddenbrock concludes that our present knowledge gives us warrant to assert merely that "bei Synapta die Syatozysten lediglich im Dienste einer speciellen Fluchtbewegung stehen, welche die Thiere vom der Oberfläche in die sichere Tiefe führt, und dass ihnen eine sonstige Funktion nicht zukommt."

b. Observational. The following experiments on Synaptula hydriformis by no means prove that the statocysts function as positional organs, but they furnish evidence in that direction.

Synaptula hydriformis, in contrast to sand-digging forms, is decidedly negatively geotropic. Light is so potent a stimulus that several experiments in which specimens had to go towards the light in order to carry out their usual response to gravity failed to show any results. Experiments conducted in a dark-box open at the top and placed in the center of the room were successful, since in this way the intensity of the light was sufficiently reduced. The animals have no difficulty in creeping up the vertical walls of a glass finger-bowl, therefore a glass plate was used for the trials.

The least angle with the horizon which would induce the synaptulas to crawl upwards was 20°. At 18° they went down or to one side. At 20° 60 per cent went up, while at 23° and above practically 100 per cent went up.

I repeated Clark's ('99) experiment of gently changing the position of the plate on which a Synaptula was moving. The plate was held at an angle of 25° with the horizon, one edge resting on the bottom of the dish, and when the animal had started well on its way toward the top, the plate was gently turned until an adjacent edge rested on the bottom. This was done so gently that the body of the Synaptula was kept in its former position on the plate, thus avoiding a displacement of the body by gravity which would have influenced its orientation when it fell. In every case the head end turned and bent upwards at right angles to the rest of the body, and then, as its tentacles pulled the Synaptula upwards, after orientation had been perfectly accomplished, the body finally fell so that the animal lay in a straight line throughout its entire length.

These results tend to show that the head region is concerned in orientation to gravity. For further proof the 'heads' of specimens were cut off immediately back of the calcareous ring. Both these 'heads' and the decapitated bodies were used in experiments. In every instance the head portions climbed the vertical walls of the vessel, while the posterior portions remained on the bottom in an inert condition. Naturally one can not conclude from such experiments that the posterior ends are unable to orient to gravity, since as a matter of fact they were deprived of their organs of locomotion,—the tentacles,— and therefore might not be able to show any response. To see whether lack of locomotor organs prevented response, I took whole specimens, anaesthetized them in chloretone, and cut off their tentacles. When on the next day they had recovered from anaesthesia, I placed these tentacle-less specimens together with 'headless' ones, anterior ends downward, upon a plate covered with cloth. Although neither the tentacle-less nor the headless animals could climb, they were able to cling to the cloth by means of their anchors. When the plate was inclined at an angle of 30° with the horizon, the extreme anterior ends of the tentacle-less specimens bent around so that their bodies were in the form of a J, while the headless ones remained as they were placed, or at most became slightly bowed. The organs concerned with orientation to gravity therefore can lie only in the anterior end of the animal near the calcareous ring.

To show that this was a true response to gravity, and not to the need of oxygen, I placed several 'heads' in a finger-bowl completely filled with sea-water and inverted in a second dish of sea-water. The rim of the finger-bowl was slightly raised so that the supply of oxygenated water might enter from below.

The 'heads' in every case went straight up the (inside) wall of the bowl directly away from the supply of oxygen.

In contrast to the sand-inhabiting synaptids, like Synapta inhaerens (Semon, '87), but in agreement with others, like Leptosynapta bergensis (Becher, '07, '09), Synaptula hydriformis appears not to respond to vibrations. In individuals placed in a dish resting on an arm of a tuning-fork (run by electricity) whose vibration rate was 256 vibrations per second, no response was observable either when the fork was suddenly started or stopped, or during uninterrupted vibration. Tapping lightly with a metal rod on a dish containing synaptulas failed to call forth a response. Not even when the blow was so severe that there was danger of breaking the dish could any response be detected. Nevertheless a drop of water falling through a distance of 5 cm. on to the surface of water in a finger-bowl containing synaptulas was sufficient, in most cases, to cause partial closing of the tentacles and a dropping of the specimens to the bottom of the dish. A fall of a single drop of water through less than 5 cm. produced, in general, no effect. One individual did not respond until the drop had fallen through 10 cm.

These experiments show (1) that Synaptula hydriformis does not respond to vibrations of relatively high frequency, (2) that it is distinctly negatively geotropic, and (3) that the organs which respond to the force of gravity are located at the anterior end of the animal very near the calcareous ring. Now, this is exactly the position where the statocysts are to be found. These organs are so small and in such a location that the difficulties of removing them for experimental purposes are great. Indirect evidence of the kind brought out in the above experiments must therefore decide the question as to whether the statocysts are truly organs of orientation.

Since Clark ('98) has shown that the structure of these statocysts meets the requirements for 'positional organs,' and since my experiments show that the animal does orient to gravity, and that the organs concerned with this response can lie only in the region where statocysts are to be found, I think it safe to conclude that the statocysts are the organs concerned in the orientation of Synaptula hydriformis to gravity. My experiments show further, that Synaptula hydriformis does not respond to such vibrations as are said to produce a tone when they reach the ear of man.

3. The effect of light

a. Historical. One of the earliest observers, and probably the first to record physiological experiments on synaptids, was Quatrefages ('42). He tried the effect of light, [sounds] vibrations, mechanical and other stimuli upon his Synapta duvernaea (S. inhaerens) and states (p. 29), "Je n'ai pu reconnâitre chêz elles la moindre trace de vision, proprement dite, non plus d'audition ou d'odorat." Nevertheless he thought the activity of these synaptas was reduced during the daytime. When he exposed them to the rays of his lamp concentrated by means of a lens, "elles en étaient évidemment incommodé esquelle que fût la partie du corps placée au foyer, mais surtout lorsqu'un dirigeait cette lumière sur les tentacles; on les voyait alors se détourner et quelquesfois se contracter et revenir en partie sur elles meme" (p. 28). His physiological observations were evidently forgotten for some time, for the discussion of sense organs in synaptids became one of merely anatomical relations.

The first description of the 'eye-spots' of synaptids was given by Müller ('50 b, p. 226; '52, p. 16). Semper ('68, p. 152) concluded that the sense organs which Müller described, the 'Augenflecken' and 'Gehörblasen,' were both somewhat problematical. "Ob die von Müller entdeckten Augenflecke der Synapten wirklich als Sinnesorgane, analog den mit dem Nervensystem in Verbindung stehenden Pigmentflecken verschiedener Thiere, aufzufassen sind, ist noch nicht zu entscheiden." Baur ('64) found that in Synapta digitata the pigment masses which lie at the bases of the tentacles are not different from those scattered over the surface of the body, and Hamann ('84, p. 26) agreed with Baur that they should not be considered as 'Augenflecke,' but simply as 'Plasmawanderzellen.' Semon

('87) seems to have been impressed by Quatrefages' observations and tried several experiments on Synapta inhaerens and S. digitata. He was, however, unable to discover any reaction to photic stimuli. Sudden strong increase of light or sudden shading gave no results. He was therefore induced to agree with Baur and Hamann that these pigment spots were not true eye-spots.

Ludwig und Barthels ('91), on the contrary, are emphatic in their statement that the so-called eyes in Synapta vitatta and S. vivipara (Synaptula hydriformis) are undoubtedly sense organs. Probably their assertion is based on morphological grounds, though they do not so state. Clark ('98), too, says that "there can be little doubt that in Synaptula vivipara these eyes are actually of service as light-detecting organs," though he reports no experiments to prove his position, merely remarking: "That this covering (the mesodermal layer surrounding the nerves to the eye-spots) may be affected by light is probable, for its color is due to the pigment it contains." Yet he also states, "There is no reason to assume that the pigment in other parts of the body is any different from that around the eyes."

b. Observational. It is a fact that in several of the lower animals, eye-spots, so-called from morphological considerations, have been clearly shown not to function as eyes at all (Nagel, '96, p. 34). In other cases, although eyes are present as true photoreceptors, other parts of the covering of the body are also sensitive to light (Parker, '03). Whether the eye-spots in Synaptula hydriformis are truly special photoreceptors, I have as yet been unable to ascertain. One thing, however, is certain, the whole surface of the body is sensitive to light.

This Synaptula is decidedly negatively phototropic. When placed facing a window in the daytime or before an electric lamp at night, it at once turns from the light and moves to the opposite side of the dish in a fairly straight line. The changes of body position in this orientation are exactly those figured by Crozier ('14 b, p. 12, fig. 1) for Holothuria captiva. Consequently Mast's ('11, p. 211) sweeping statements—"The Echinoderms are peculiar in that they can move with any side ahead," "The lack of orientation in moving from a source of light is much more striking in the Holothurians," and "there is no orientation in these animals"—hold for species like Thyone briareus (Peare, '08), but not for Holothuria surinamensis (Crozier, 14 a), Holothuria captiva (Crozier, '14 b), or Synaptula hydriformis.

If the heads of synaptulas are cut off just back of the tentacles, they, too, will move to the side of the dish away from the source of light, whether it be the sun (direct or indirect light), or an electric (32 candle power) lamp. When the posterior portions of these headless animals are placed with their anterior ends in the sunlight, they also show response to the light by bending their cut ends away from the light, so that the body becomes bent into a U. If, however, these posterior portions are placed some distance (five feet) from a window on the side of the room opposite that where the sun is shining in, or near an electric lamp, they do not orient to the light, but remain practically as they were placed. If the tentacles only are cut off (the eye-spots being left intact), the animals bend their anterior ends away from the light, and gradually bring their posterior ends around until the animal lies in a straight line headed away from the source of light. In this respect they differ from the headless synaptulas, since the latter remain bent. Posterior headless pieces placed in the dark with their cut ends arranged in a line, were found after 30 minutes to be in practically the same position as that in which they had been placed at the beginning of the experiment; therefore the bending away from the light of the headless portions is a true photic response, and not the result of injury.

Spots of light thrown on different parts of the body of Synaptula showed that all parts were sensitive to light. Experiments were first tried in which the synaptulas were placed on the bottom of a dish containing 20 cm. of water. A spot of sunlight, concentrated by means of a lens of 25 cm. focal length, was thrown on the various parts of their bodies. The response, no matter what portion of the body was illuminated, was so violent, that it seemed almost impossible that it could result from photic stimuli alone. It was found that if a similar spot of light was thrown on a thermometer placed in the same situation, there was an immediate rise from 27° to 34°C. A column of sea-water 20 cm. high was therefore not an efficient heat screen. Nevertheless, other experiments had shown that synaptulas did not respond to a sudden change of temperature from 27° to 34°C. It was thought best, however, to eliminate any possible stimulation from heat rays. Accordingly the animals were placed in a small dish within a box whose sides were painted black. Over a hole in the top of the box was placed a glass tank containing sea-water to the depth of 27 cm. The sunlight came through the water, passed down into the box, and was concentrated on the synaptulas by means of small hand lenses of 2 and 2.5 cm. focal length. When this very small spot of light was allowed to fall on a person's finger, he was unable to perceive any rise in temperature. If the light was thrown on a thermometer, no change could be noted. The results obtained under these conditions are given in table 4.

TABLE 4

The effect of local stimulation by light

REGION STIMULATED	RESPONSE
Base of tentacles	Draws tentacles in. Shortens whole body. Local constriction
Body anterior to middle	Local constriction only
Body posterior to middle	Local constriction only
Posterior end	Local constriction. Shortens whole body. Bends posterior end away

All parts of the body of Synaptula respond to local stimulation by light of the intensity used in these experiments. The middle portion of the body gives less vigorous response than either the head or the posterior end. The order of sensitivity of parts is, therefore, the same as that for other holothurians (Crozier, '14 a, 14 b; cf. also Parker, '08).

Headless animals were tested in the same way and were found to give reactions similar to those of entire animals. The severed heads, however, behaved somewhat differently. When the spot of light from above was thrown on them, they at once turned and moved off at approximately a right angle to the direction in which they were first moving. Only once did a head attempt to draw in its tentacles; that was after the spot of light was kept focussed on it as it moved about. At least 10 seconds of constant stimulation was necessary to produce this reaction, whereas in entire animals this response was practically instantaneous.

The results of these experiments make it seem doubtful if the 'eye-spots' are 'light-detecting' organs. For, first, the whole body is sensitive to light, and, secondly, parts of the body without eyes are able to orient away from a source of light. Nevertheless, one must take into account the fact that in headless, and therefore eyeless, specimens orientation did not occur in light of less intensity than direct sunlight, while the heads of the same animals, which contained the eyes, did orient under the same conditions. This is simply further indication that the head end is more sensitive than other parts of the body, and in no way does it prove that the presence of the eye-spots is responsible for the greater sensitivity. Parker ('08) found that the anterior end of Amphioxus, which contains a so-called eye-spot, was more sensitive to light than either the middle or posterior part of the body. Yet he showed that this eye-spot was not a photoreceptor, because light focussed upon it elicited no response from the animal. The true photoreceptors in Amphioxus were certain organs distributed along the nerve cord, more of them being found at the anterior end, the region of greater sensitivity. This has been confirmed and further demonstrated by Crozier ('17). Similarly in Synaptula, the whole surface of the body is sensitive to light, the anterior end being more so than the other parts, perhaps in spite of, rather than because of, the eye-spots.

4. The effect of heat

a. Historical. Few investigations have been made upon the reaction of holothurians to heat. Crozier ('14 a) found that none of the several holothurians which he tested seemed to be "equipped with anything which might properly be called a temperature sense." Kafka ('14, p. 214) dismisses the subject with little more than the statement, "Die Holothurien scheinen für Temperaturänderungen ziemlich unempfindlich zu sein."

b. Observational. Synaptula hydriformis evidently possesses only a feeble temperature sense. If a half cubic centimeter of water at any temperature between 14° and 42° C. is allowed to flow gently from a pipette upon the tentacles of a Synaptula immersed in sea-water of a temperature of about 27°C., there is no response. But water at 10° or less, and at 46° or more thus applied, invariably causes the animal to respond. Table 5 gives the percentages of responses for these and other temperatures.

TABLE 5

The effect of 0.5 cc. sea-water at different temperatures flowing on tentacles

TEMPERATURE	PER CENT OF RESPONSES
8°	100
10°	100
12°	77
13°	65
14-42°	0
43°	30
45°	88
46°	100

A second method used in testing the temperature sense was that of carefully lifting a Synaptula out of water at 27°C. (the normal) and suddenly immersing it in water at the desired temperature. The animal was allowed to remain 3 minutes at the given temperature and then carefully returned to water at 27°. Table 6 gives the results of such trials.

Here the limits between which there were no responses were 20° and 40°. Beyond these limits one or more vigorous contractions of the whole body were given, followed by relaxation at the higher, and partial contraction at the lower temperatures. To produce death in 3 minutes a temperature of 46° was necessary.

TABLE 6

The effect of suddenly transferring Synaptulae from sea-water of 27°C. to that of different temperatures, leaving them 3 minutes, and then returning them to that of 27°

TEMPERATURE	EFFECT OF CHANGE	EFFECT OF RETURN
14°	Vigorous general contraction of whole body. Constriction back of tentacles. Keeps moving	Behaves normally after lengthening of body
15°–18°	Same as above	Same as above
19°	Less vigorous contraction. No constriction	Same as above
20°–39°	No response	No response
40°	Three contractions of whole body. Posterior remains contracted. Tentacles still move	2–3 peristaltic waves. Behaves normally
43°	Same as at 40°, but entire relaxation after 2 minutes	Same as from 40°
44°	More vigorous contraction. Anterior end remains contracted. Posterior relaxes	Same as from 40°
45°	Vigorous contraction. Followed by complete relaxation	Vigorous contraction. Peristaltic movements in posterior end only. Anterior end killed
46°	Feeble contraction. Died at once	No recovery

Local application of heat was tried with negative results. A glass tube of small bore was bent into a narrow U, the ends of which passed through a cork for convenience in holding. By means of a siphon and rubber tubing, hot water was continually passed through the U-tube. The mean between the temperature at which the water entered and that at which it left the tube was taken as the temperature at the middle region of the system where the U-tube was situated.

Water at 27° was first run through. It was found that there was no response when the tube was held near a Synaptula, or even when it touched the animal, if this was done with sufficient care, except that when in contact with the tentacles they would attach themselves to the tube and the animal would attempt to climb along the tube. Water at 47° and even at 50° failed to show any effect, although both temperatures are above the killing point, and the water surrounding the U-tube must have been raised considerably above 27°. Indeed, the action of the tentacles was the same as when the water at 27° was running through it, since they attached to the tube in the same manner.

From these results one must conclude that the temperature sense of Synaptula hydriformis, while not entirely absent, is very poorly developed and probably not located in any particular regions. Since in its natural habitat the animal is not subjected to sudden or great changes of temperature, it is not surprising to find this sense practically lacking.

5. *The effect of chemical agents*

a. Historical. Chemical agents may produce in vertebrates the sensation of smell or taste according as they stimulate the olfactory or gustatory organs, or they may affect the free nerve endings of the epidermis, the receptors for the common chemical sense (Parker, '12; Crozier, '16 a). These three kinds of receptors are found in aquatic as well as land vertebrates (Sheldon '09; Parker, '12). Among aquatic invertebrates some mollusks have been shown to have separate senses of smell and taste (Kafka, '14, p. 269), as proven by topographical experiments and by the difference in histological makeup of the organs. Copeland's ('17) recent experiments on snails give further proof of the separateness of these senses in mollusks.

Among the echinoderms the starfish was thought by Romanes ('85) to have a sense of smell located in the ventral surface of the rays. More careful experiments by Jennings ('07) on the starfish Asterias forreri showed that the pedicellariae on the dorsal surface responded to the juice of crab-meat held a little above the surface of the animal. It is therefore probable that there is present only a general chemical sense in the starfish and that this is distributed over the whole surface of the body.

The reactions of holothurians to chemical agents have been studied intensively in only one species, Holothuria surinamensis (Crozier, '14 a), while only scattered observations on the chemical sense of synaptids are to be found in the literature. Quatrefages ('42) placed specimens of Synapta inhaerens in solutions of opium to quiet them, but was unsuccessful in attaining this end. He also found that fresh water had practically no effect on this species, and that pieces of the animal would remain alive in it for some eight days. Synaptids were thought by Semon ('87) to have a very keen sense of smell and taste, which he located in the cup-shaped outgrowths on the inner face of the tentacles. These organs had been noted by Quatrefages ('42, Planche 4, fig. 1 and Planche 5, fig. 3), who called them 'ventouses.' These are the same structures as Müller's ('50) and Baur's ('64) 'Saugnäpfe' and Hamann's ('84) 'Sinnesknospen.' Semon's reason for locating these special senses in these organs are as follows: (1) pieces of food attached to the ends of the tentacles as they are bent down to the mouth must pass by these cups; (2) histological study of the structure of these organs shows—by far the more weighty evidence in his opinion—that they are lined with cilia and that nerves pass from them to the tentacle nerves. Such 'proof' is far from conclusive. Moreover, when Semon makes the statement that bringing a strong-tasting substance, such as chloral hydrate, into the neighborhood of the tentacles causes a most vigorous reaction, one realizes that he is speaking of what we now call a common chemical sense, and nothing so definite as smell and taste. To account for the fact that this 'strong-tasting' substance, chloral hydrate, also stimulated any region of the body to which it was applied, he had to suppose that the 'touch-papillae' contained taste cells, or that such cells were scattered over the surface of the body "to inform the animal as to the good or bad quality of the sand." Clark ('99) found that Synapta rosea and S. inhaerens moved away from rank smelling substances placed in the water near them, even though these substances were not touching the animals. Clark ('98, '07) has followed Semon's example in calling the cups on the tentacles gustatory organs. He remarks, "There seems to be little doubt that these cups serve as organs of either taste or smell, although the evidence is not conclusive."

There are, however, synaptids which lack these cups, among them is Synaptula hydriformis, and yet this species is very sensitive to chemical agents. The function of the 'gustatory cups' therefore seems to be still unsettled. Clark ('07) states that synaptids which possess eye-spots never have gustatory cups, and vice versa. Upon the ground that the functions of these two organs are those suggested by their names, the relation of the presence of one of these organs to the absence of the other is hard to explain.

b. Observational. Synaptula hydriformis, like the majority of aquatic animals, is sensitive to chemical agents over the entire body. The most vigorous reactions are given when the tentacles or the head end are stimulated. For this reason experiments to determine the limits of sensitivity were performed by allowing 0.5 cm. of a solution of a given reagent to flow down the inside of the vessel for 2 to 3 mm. till it reached the surface of the water directly above the tentacles of an animal moving about just under the surface. More constant reactions were obtained when the animal was tested in this position than when it was crawling on the bottom of the dish. Trials with ordinary sea-water were made before each experiment, and often between successive exposures to the chemical solution. With rare exceptions there was no response to sea-water. Ten minutes was allowed between successive trials, so that fatigue of the sense organs might not occur, and so that the animal might resume its position at the top of the dish if it had dropped to the bottom. In general the same chemical agent was not used in two consecutive trials in order to avoid a possible accumulative effect. The following record is typical, x denoting no response.

July 25. Specimens collected this morning

	SPECIMEN				
	No. 1 (Green)	No. 2 (Green)	No. 3 (Red)	No. 4 (Red)	No. 5 (Green)
M/100 NaCl....	x	x	x	x	x
M/100 KCl.....	x	x	x	x	x
M/100 Na acetate..........	x	x	x	x	x
M/10 KCl......	Draws in tentacles, drops to bottom of dish	Draws in tentacles, drops to bottom of dish	Animal drops to bottom of dish	Animal drops to bottom of dish	Draws in tentacles, drops to bottom of dish
M/10 Na_2 SO_4..	x	x	Drops	x	x
M/10 Na acetate..........	x	x	x	x	x
M/20 KCl......	Drops	Drops	Drops	Drops	Drops
M/10 $MgCl_2$....	x	x	x	x	x
M/10 cane sugar...........	x	x	x	x	x
M/10 $MgCl_2$....	Draws in tentacles, drops	Same as no. 1	Same as no. 1	Same as no. 1	Same as no. 1

In table 7 are given the limiting concentrations of the various classes of chemical agents. These were determined by making at least two trials on each of five or more different individuals. If, with a certain concentration, definite responses were obtained in half the number of trials, this concentration was considered to be the limit. Upon trying double this concentration it was invariably found that a decided response to every trial was given by every individual, and that to half this concentration no reactions at all were shown. Table 8 has been compiled for purposes of comparison.

Synaptula hydriformis, in contrast to Synapta inhaerens (Quatrefages, '42), is very sensitive to fresh water. Indeed fairly slight changes of osmotic pressure call forth a very decided reaction. 8 cc. ordinary sea-water + 2 cc. rain water causes a vigorous reaction, while 9 cc. sea-water + 1 cc. rain gives none. If the concentration of the salts in sea-water is taken as 5/8 M, (Mayer, '11, '14), then the former dilution corresponds to 1/2 M, i.e., a change of 1/8 M is sufficient to cause a reaction. On the other hand, 6 cc. sea-water + 4 cc. sea-water

TABLE 7

Limiting concentrations of chemical agents

	REAGENT	RESPONSE TO	NO RESPONSE TO
Sweet	Glycerine	1/2 M	1/4 M
	Sugar (cane)	1/2 M	1/4 M
	Saccharine	1/200 M	1/400 M
Sour	Acetic acid	1/400 M	1/800 M
	Hydrochloric acid	1/600 M	1/900 M
	Oxalic acid	1/200 M	1/400 M
Anaesthetics	Alcohol	1/5 M	1/10 M
	Ether	1/100 M	1/200 M
Alkali	Ammonium hydrate	1/200 M	1/400 M
Salts	$NaCl$	1/4 M	1/8 M
	KCl	1/40 M	1/50 M
	KBr	1/40 M	1/80 M
	$CaCl_2$	1/20 M	1/40 M
	$MgCl_2$	2/5 M	1/5 M
	$NaSO_4$	1/8 M	1/10 M
	KI	1/80 M	1/160 M
	NH_4Cl	1/15 M	1/20 M
	$NaC_2H_3O_2$	1/10 M	1/20 M

TABLE 8

Minimum concentrations of chemical agents which will call forth responses when applied to the mouth of certain vertebrates or the tentacles or mouth region of certain invertebrates

	HCl	NaOH	NaCl	QUININE	SUGAR
Amphioxus (Parker, '12)	1/500 M				N.R.[1]
Ammocoetes, (Parker, '12)	1/1280 M	1/1000 M	1/40 M	1/640 M	N.R.
Mustelus, (Parker, '12)	1/75 M	1/10 M			N.R.
Amiurus (Parker, '12)	1/20 M	1/100 M	1/50 M	1/150 M	N.R.
Man (Parker, '12)	1/1000 M	1/400 M (KOH)	1/50 M	1/25,000 M	1/50 M
Holothuria (Crozier, '14 a)	1/500 M	1/500 M (NH_4OH)			
Synaptula hydriformis	1/600 M	1/200 M	1/4 M	1/10,000 M	1/2 M

[1] N.R. signifies that there was no reaction.

which has been evaporated to one-half its normal volume gives a reaction, while 7 cc. ordinary sea-water + 3 cc. of the concentrated sea-water fails to call forth a reaction. The former concentration corresponds to 7/8 *M*. The range of concentrations between which osmotic pressure does not serve as a stimulus is therefore 1/2 *M* to 7/8 *M*. The significance of these limits will appear in the discussion of the effect of certain agents such as sugar and glycerine.

Since changes in osmotic pressure caused such marked reactions, it was impossible to make up solutions in pure water. 5/8 *M* NaCl or KCl in pure water produced violent reactions, from which it required several minutes for the individual to recover. Solutions were therefore made up in sea-water. Solid agents were dissolved directly in sea-water, and the normality of the solution was reckoned as if pure water had been used. Liquids like HCl were added in double the concentration desired to sea-water evaporated to one-half its normal volume. It is by no means claimed that these limits are as accurate as the table suggests. The first drops of the solution must necessarily be much diluted by having to pass through several millimeters of sea-water before reaching the Synaptula. The last part of the discharge must, however, flow against the animal in approximately its original concentration. If these limiting values err, they do so in being too high; still they are significant for comparing the effects of different agents on this one species, even if they may be less so for comparing the degree of sensitivity of Synaptula with that of other animals.

Parker ('12, p. 228) considers that aquatic vertebrates will not respond to that class of chemical substances which in man produces the sensation of sweetness. Crozier ('14 a, p. 289) believes that some sugars may prove stimulating, since Holothuria surinamensis responds to maltose and glycerine. The 1/2 *M* cane sugar and glycerine solutions to which Synaptula responds (table 7) have a total concentration (salts in sea-water plus sugar or glycerine) of 9/8 *M*, while the 1/4 *M* solution, to which it does not respond, has a total concentration of 7/8 *M*. It is evident therefore that we are dealing in the case of the reactions of Synaptula to sugar and glycerine simply with an osmotic pressure phenomenon, and not with a response comparable to our gustatory sensation of sweetness. The close correspondence of the limiting concentrations for stimulation by increased osmotic pressure (1) when the sea-water is concentrated by driving off water and (2) when sugar or glycerine are added, shows that the method is at least consistent with itself.

Saccharine, however, proves to be very stimulating. Whether Synaptula actually experiences a sweet sensation from a solution of saccharine, it is impossible to state. In man saccharine is sweet to the tip of the tongue, but rather bitter to the back of the tongue. This difference is more pronounced in parabrombenzoic sulphinid, a bromine substitution product of saccharine (Howell, '16, p. 298). It may be possible that in Synaptula only a bitter (alkaloid) effect is perceived when the animal is stimulated by a solution of saccharine.

Of the three acids tried, HCl caused a response at the lowest, acetic at a slightly greater, and oxalic at a still greater concentration. Neglecting the suppression of ionization of HCl due to the presence of Cl ions already in the sea-water,—the effect of which is very slight (Chick, '13, p. 333),—there would be in $1/600\ M$ HCl a hydrogen ion concentration of about $0.0016\ N$, since HCl at that dilution is practically wholly dissociated. But acetic acid at $1/400\ M$ is slightly less than 8 per cent dissociated, therefore the concentration of the hydrogen ion in the limiting concentration of HCl for stimulation is some 8 times that in the limiting concentration of acetic acid. This is exactly the phenomenon to which Crozier ('16 a) refers as occurring in human taste. He suggests, as an explanation of this anomaly, that "potentially ionizable hydrogen" is present "within the undissociated acid molecules, though secondary ionization may also play a part."

Two alkaloids only were tried, strychnine and quinine. The former is the more stimulating (cf. Crozier, '14 a). The sensitivity of Synaptula to these reagents is remarkable. It responds to a solution of $1/10{,}000\ M$ quinine; but even in man the limit is only $1/26{,}000\ M$ (Parker, '12). After stimulation with strychnine and especially with quinine, Synaptula responds vigorously to very weak stimuli of any sort. An application of 0.5 cc. of 1/10,000 *M* quinine will for hours afterwards render useless all further experimentation on an individual, and after one or two drops of 1/1000 *M*, the slightest touch on the tentacles is sufficient to cause a sudden and violent withdrawal of all the tentacles into the mouth region, even twenty-four hours after the application of the quinine. Henri ('03) found that after an application of a weak solution of strychnine sulphate to the holothurian Stichopus regalis there was a very marked augmentation of sensitivity. Jennings ('07, p. 69) found that the starfish Asterias forreri, after stimulation by certain chemical substances, gave a much readier response to mechanical stimulation. Crozier ('14 a, p. 285) obtained similar results on Holothuria. Even in man this is true, since in cases of strychnine poisoning "the slightest stimulus, such as a faint noise, a draught of air, etc., is sufficient to throw the patient into general convulsions" (Lickley, '12, p. 17; cf. Herrick, '15, p. 65).

Not only does this marked increase in the sensitivity of Synaptula to weak stimuli follow after application of alkaloids, but also after excessive or severe stimulation, such as keeping them in water at 42°C. for several minutes.

If the kations of the chlorides used in the experiments on stimulation with salts are arranged in a progressive series beginning with Mg, which is the least stimulating, and therefore has the greatest limiting concentration, we find the order, Mg, Na, NH_4, Ca, K, this being the usual so-called liatropic series (Höber, '11, p. 497; Crozier, '14, p. 289, '16 a, p. 345). But since 1/2.5 *M* $MgCl_2$ in sea-water has a total concentration of 1 *M*, the response to this salt is probably one to increased osmotic pressure only.

An anion series where Na was the kation of each salt runs as follows: chloride, sulphate, acetate (Höber, '11, p. 487). Although the limiting concentrations of KCl and KBr appear the same in the table, KBr is slightly the more stimulating of the two, since the number of reactions to 1/40 *M* KBr was at least 50 per cent greater than to 1/40 *M* KCl. This is also indicated by the fact that the concentration of KCl which just failed to stimulate Synaptula was 1/50 *M*, while for KBr it was 1/80 *M*. Therefore we find this series to be: chloride, bromide, iodide (Höber, '11, p. 487).

No attempt was made to carry out experiments on 'balanced' solutions, since calcium-free sea-water proved stimulating. In 60 trials with calcium-free sea-water, conducted at different times during the summer on many different specimens of Synaptula, 31 resulted in vigorous responses, 11 in slight responses, and 18 in no response. There was no reaction to magnesium-free sea-water. The effect of calcium-free sea water is plainly shown in the following record. The individuals were gently transferred from ordinary sea-water and totally immersed in the calcium-free sea-water. Similar transference from normal sea-water to normal sea-water, carried out as a check, caused no reaction.

July 26

4.15 p.m. Five individuals transferred to calcium-free sea-water. All five at once contract body, then draw in tentacles violently, then straighten out.

4.16 p.m. Violent peristaltic waves of body wall in quick succession. No attempts to climb the sides of the dish. Squirm about on bottom. Three individuls defecate.

4.20 p.m. All much contracted, lying motionless on bottom.

5.10 p.m. Do not respond to slight touch, or even vigorous poking, or to solution of 1/400 *M* HC.l

5.15 p.m. Restored to normal sea-water.

5.20 p.m. Four perfectly recovered. Climb walls. Respond to touch, etc. Others still motionless.

July 27

9.30 a.m. All five animals in perfect condition. Respond to touch, etc. Calcium-free sea-water therefore acts as an anaesthetic.

Local application of solutions of chemical agents to different parts of the body gave characteristic results. Fifteen trials where 0.5 cc. 1/10 *M* KCl was allowed to flow very gently from a capillary pipette ending about 2 mm. from the regions to be stimulated gave the following:

1. On tentacles. Tentacles close and animal drops.
2. On mid-body. Local contraction, which initiates a peristaltic wave.
3. On posterior end. Local contraction. Posterior end lashes about from side to side. In one case the animal contracted its tentacles and dropped.

The same results as for KCl was produced by 1/10 *M* $CaCl_2$, Na acetate, or Na citrate.

1/10 *M* NaCl, $MgCl_2$, or Na_2SO_4 gave the same results as a current of ordinary sea-water, i.e., were not stimulating. To be more certain that the effects of 1/10 *M* KCl, $CaCl_2$, Na acetate, and Na citrate were not due to currents, a crystal of oxalic acid was held in forceps just over a Synaptula. When the crystal was above the tentacles they were at once drawn in violently; if over any other portion of the body, there occurred deep local constriction, and the whole body posterior to the stimulated region became greatly contracted; if over the extreme posterior end, local contraction took place, a shortening of the whole body, and a lashing about of the posterior end.

Synaptula hydriformis is therefore very sensitive over its entire body to changes in osmotic pressure and to chemical agents, more so at the anterior end, less at the posterior, and still less in the mid-body regions. It responds to the same categories of chemical agents as do the vertebrates (Crozier, '14 a), i.e., acids, salts, sugars(?), alkaloids, alkalis, and anaesthetics.

6. *General discussion*

It cannot, as yet, be stated whether there have been developed in this holothurian separate sense organs for the different classes of chemical stimuli, or indeed for chemical stimuli in general as distinct from tactile stimuli, etc. The former seems highly improbable, and the latter perhaps doubtful. Aside from the eye-spots and the otocysts, only one type of sensory cell has been described in synaptids (Clark, '98, '07; Retzius, '06), namely the usual invertebrate bristle cell terminating at its deep end with a fiber which connects with a nerve net. The presence of such cells in the vertebrate olfactory epithelium has led Parker ('12) to consider this as the primitive type of sense organ carried over from the invertebrates to the vertebrates. Others (Herrick, '08; Sheldon, '09) have considered the free nerve terminations, which serve as the receptors for the common chemical sense in the vertebrates, to be the primitive type. In support of the former view, it may be urged that not only is the histological structure of the vertebrate olfactory sense cell the same as that of the invertebrate bristle cell, but the physiological characters of the two kinds of cells are similar. (1) The nature of the stimulus is the same, viz., chemical substances, (2) they are 'distance receptors,'[1] and (3) a very minute amount of substance serves as a stimulus.

Nagel ('94) has advanced the idea of the existence of 'universal sense organs' in the invertebrates, i.e., organs which, instead of being capable of receiving stimuli of only a limited range, can receive stimuli of all sorts. In the course of evolution from the lower to the higher forms, certain of these 'universal sense organs,' according to this view, became more restricted in their sensitivity and responded to fewer and fewer classes of stimuli, until finally such specialization occurred as is shown in the present condition of man, where there are no recognizably 'universal sense organs' but some twenty (Herrick, '15, p. 74) special senses.

It may be that Synaptula affords an example of an animal in which these universal sense organs exist. The methods of determining whether or not sense organs are specialized to receive one class of stimuli only are (1) to apply these stimuli on separate portions of a given area of body surface, and (2) to anaesthetize, if possible, a surface differentially. The latter method seems to me untrustworthy when used alone. A 'universal sense organ' when slightly anaesthetized might not respond to light, but might respond to other more vigorous kinds of stimuli, such as the application of an acid. If, however, one finds, in addition to differential anaesthesia, the existence of definite regions which respond, e.g., to touch alone, or chemical agents alone, then one must conclude that special sense organs are present. The same conclusion is drawn if one finds that the histological structure of the sense organs in one region differs

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[1] In strict analysis 'distance receptor' is a misnomer, for organs to which this is applied depend, like all other sensory organs, on actual contact with the stimulating agent. It is therefore probable that '(2)' and '(3)' are only different ways of expressing the same thing.

markedly from that of sense organs in other regions. But neither of these conditions have, as yet, been demonstrated for synaptids

In Miss Langdon's ('95, p. 215) account of the sense organs of Lumbricus, she estimates that in a worm 19 cm. long with 152 metameres, there are 150,000 sense organs present, about 1000 to a single metamere. The magnitude of the task of stimulating separate sense organs in the earthworm can thus be readily appreciated. In regard to the histological structure of these organs she says (p. 226), "Since these sense organs form the only known sensory apparatus of Lumbricus, and since their structure is not visibly different in different parts of the body, it is likely that they are sense organs of a general nature capable of reacting to mechanical, chemical, thermal or luminous stimuli." She also finds (p. 218) that "the sense organs are distributed over the entire surface of the body, but are most numerous and largest at each end." Since these features of the worm are exactly paralleled by those of Synaptula, it would not be unreasonable to draw the same conclusion here, i.e., that in Synaptula also there are present "universal sense organs."

From the foregoing account it is possible to defend the following statements regarding Synaptula: (1) it has a well developed chemical sense, since it responds to many of the categories of substances which are stimulating to man, viz., sour, bitter, salt, sweet (?), and alkaline; (2) the order of sensitivity in different parts of the body to chemical agents is the same as to light, and to touch; (3) except for the eyes and otocysts, only one type of sense organ has, as yet, been described for it; (4) the relative abundance of the sense organs in the three or four chief regions of the animal is the same as the order of sensitivity in these regions to these three kinds of stimuli; chemical, photic and tactile.

In connection with the idea of 'universal sense organs', it is interesting to note, and not without significance, that, as the studies of Herrick and Coghill ('15) have shown, "in the development of the nervous system of Amphibia, the first reflex circuits to come to maturity are made up of rather complex chains of neurones so arranged as to permit only one type of response—viz., a total reaction (the swimming movement)—from all possible forms of stimulation, and that in successive later stages this generalized type is gradually replaced by a series of special reflexes involving more diversified movements. . . . . The simple reflex arc . . . . , which is adapted for the execution of a single movement in response to a particular stimulus, is the final stage in the developmental process, whose initial stages are much more complex and diffuse arrangements of neurones adapted for total reactions of a more general sort" (Herrick, '15, p. 66).

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No. 75.

FUSION OF "RHINOPHORES" IN CHROMODORIS.

By W. J. Crozier.

From The American Naturalist, Vol. LI, No. 612.

CAMBRIDGE, MASS., U. S. A.
December, 1917.

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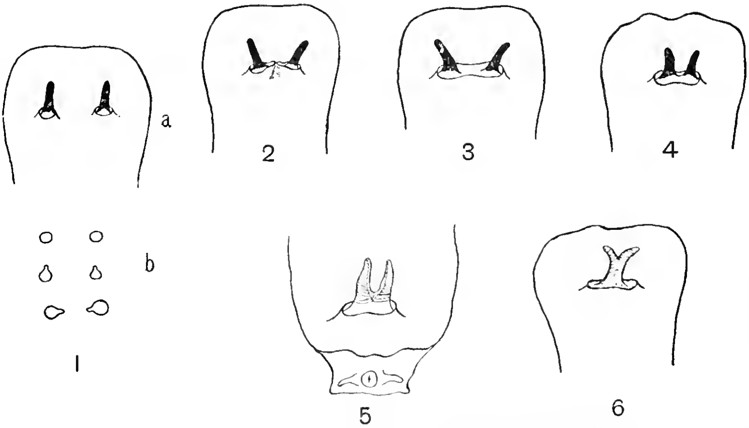
FUSION OF "RHINOPHORES" IN CHROMODORIS[1]

There have been found during the present spring nine specimens of the nudibranch *Chromodoris zebra* Heilprin which form a series exhibiting an interesting gradation in the degree of coalescence of the "rhinophores." The animals were each of average adult size, 10–12 cm. in length. In none of these cases was there any evidence that the structural variations had resulted from injury. In the period over which these individuals were obtained there were also collected about 1,000 normal specimens of the same species. These figures give, however, no precise idea of the relative frequency of "rhinophore" variation, because a larger number of specimens had been collected in previous years without any occurrence of these variations being observed.



Figs. 1–6. Outlines of anterior ends of *Chromodoris zebra* Heilprin, showing increasing degrees of fusion of the "rhinophores." Fig. 5, frontal view; the rest, dorsal aspects. Fig. 1a, the normal condition; Fig. 1b, variation in the edges of the "rhinophoral" collars of three individuals.

The bases of the two "rhinophores" of *C. zebra* are, as in other Dorids, normally surrounded by well developed individual cylindrical collars. The distal termination of a collar is usually circular in outline, but occasionally pointed at one side (Fig. 1). In two specimens the "rhinophoral" collars were closely approximated, after the fashion outlined in Fig. 2. Three specimens were found in which the "rhinophoral" collars, and the depressions into which the "rhinophores" are separately retracted when stimulated, had completely fused (Fig. 3). In

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[1] Contributions from the Bermuda Biological Station for Research, No. 75.

these animals the two "rhinophores" themselves were separated by their normal distance of about 1 cm. The next step in "rhinophore" fusion is illustrated in Fig. 4, one example having been collected. In another specimen the "rhinophores" were found to be closely united at the base (Fig. 5), while in the remaining two specimens that exhibit fusion of the "rhinophores" (Fig. 6) the process of coalescence had been pushed much further, a single stalk, giving rise at its free end to two short diverging projections, representing the normal pair of "rhinophores."

When a "rhinophore" of *C. zebra* is locally stimulated by being touched, it is retracted within its pocket, the basal collar usually contracting over it, while the companion "rhinophore" on the other side of the animal is usually not contracted. In other words, the "rhinophores" are, with reference to their retraction, subject to independent bilateral control. The process of retracting the "rhinophore" consists of two phases—the "rhinophore" is itself contractile, and it is in addition pulled down into its pocket by the action of muscles situated at its base. With the fused "rhinophores," even in such cases as that illustrated in Fig. 6, the independent bilateral control of the organs is preserved. If one tip be stimulated, that side of the compound "rhinophore" is contracted, the other (unless the stimulation be severe) remaining inert. Under slightly stronger stimulation applied to one tip of a compound "rhinophore," the contraction of the organ itself is immediately followed by the traction of muscles upon the same side of the base of the double "rhinophore," resulting in a bending of the whole structure toward the point of excitation.

The reactions of the abnormal specimens therefore support the view that these abnormal "rhinophores" have been produced by a process of fusion, probably resulting from the original close approximation of "rhinophoral" Anlagen. Two cases have been available for experiment in which one of the normally placed "rhinophores" possessed a divided tip; these divided-tip "rhinophores," superficially not unlike the single median structure above described, gave no evidence of independent control for the two tips, both parts contracting together when one tip was irritated.

It would appear that the development of the collar surrounding the base of the "rhinophore" is directly dependent upon the growth of the latter structure; in every case there was a close correspondence between the bulk of the "rhinophores" and the dimensions of the collar or collars.

W. J. CROZIER

AGAR'S ISLAND, BERMUDA

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From The American Naturalist, Vol. LI, No. 612.

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NOTE ON THE HABITAT OF GEONEMERTES AGRICOLA[1]

THE terrestrial nemerteans include a small number of species, all belonging, apparently, to one genus, but widely scattered over the world. They occur conspicuously on islands, some of which are well removed from any large mainland. The origin of these land nemerteans is a matter of some interest, and several suggestions have been made relative to the manner of their evolution. One of these terrestrial nemerteans, *Geonemertes agricola* (W.-S.), was found at Bermuda by v. Willemoes-Suhm (1874). The anatomy of this species was subsequently described in detail by Coe (1904), who gave some attention, also, to the habits of the worm. These observers, as well as Verrill (1902), agree that *G. agricola* is to be found "only along the shores of mangrove swamps and on the adjacent hillsides" (Coe, p. 566). Coe found it "not only above high-water mark but also for some distance along a zone which is covered for a short time each day with sea water," but noted that the intertidal individuals were "as a rule smaller than those living in the soil which is a little above the reach of the tide, but in earth which is nearly saturated with salt water."

Standing bodies of fresh water are absent in Bermuda. Coe consequently held that this particular species, at least, represents a land nemertean which has almost certainly been derived directly from a marine ancestor, and not, as Montgomery (1895, p. 483) had argued for the generality of land nemerteans, from a fresh-water form.

During the past several years I have repeatedly encountered *G. agricola* in a type of habitat which is significantly different from that recorded for this nemertean by the observers just quoted. In the neighborhood of every large or small mangrove "creek" or swamp which I have examined, the worm has been found, in relatively considerable quantities, well below low-water mark even at spring tides. The species occurs in the localities

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[1] Contributions from the Bermuda Biological Station for Research, No. 76.

listed by Coe, but is also common among the masses and sheets of matted sea weeds (*Laurentia, Valonia, Halimeda,* and associated plants) which cover the bottom of Fairyland Creek. Specimens were also obtained from under rocks situated a few feet beneath low-water level, in muddy bays bordered by mangroves, such as Tucker's Bay in Harrington Sound. The individuals collected in these places embraced white forms, some with a tinge of pink, others decidedly pink (as in the "pale" form figured by Coe, 1904, Pl. 1). They were 30–60 mm. in length, and some contained embryos.

In June and in July young *Geonemertes* were gotten among sea weeds in Fairyland Creek; these were 6–12 mm. in length. They were identified principally through the microscopic examination of the stylets and other organs. The stylets and stylet basis in these young specimens were of the juvenile type for this species, as figured by Coe (1904, Pl. 25, Figs. 21, 24, 25). These young specimens were in some cases pure white, in others tinged with "smoky brown." I found no pinkish specimens less than 30 mm. in length.

The observations upon the specimens of this species inhabiting salt water indicate, as Coe concluded from his study of the land-living individuals, that liberation of the young occurs in June and in July. My largest examples of *G. agricola* from the water were obtained in the spring.

Large specimens of *G. agricola* are negatively phototropic, the ocelli occupying the region of the body most sensitive toward light. They orient away from the light with diagrammatic precision. This response leads to their being found, during the day, under stones and about the roots of algæ.

It is hardly possible to credit the view that *G. agricola* has extended the variety of its habitats during the brief time since Coe's studies were made (1903); it is therefore necessary to believe that this species of nemertean is not only terrestrial in the proper sense, but truly marine as well. There seems no good ground upon which to distinguish and separate the individuals found respectively on land, in the intertidal zone, and definitely in the sea water. The terrestrial "variety" may then be regarded as having originated, perhaps not so very long ago, from the form which is undoubtedly marine—unless one is prepared to believe that, introduced as a terrestrial form, it has at some time secondarily taken to the sea after a protracted evolution as a land animal. This case seems to have some resemblance to that of a grapsoid crab at Bermuda, *Sesarma ricordi* M.-Edw., of which a terrestrial variety has been described by Verrill (1908, p. 328). It is my impression that the larger marine specimens of *G. agricola* are less hardy, more easily caused to fragment by handling, than are those taken on land. This may, however, be merely a physiological consequence of differences in habitat, which could be exhibited within the life-history of a single individual. I have not been able to keep the salt water specimens alive after abruptly transferring them to damp earth. The young individuals, however, are quite hardy, and seem capable of enduring this treatment for several days at least.

These observations add further, and possibly final, weight to the argument that some, at least, of the land nemerteans have proceeded directly from ancestors inhabiting salt water.

W. J. CROZIER

AGAR'S ISLAND, BERMUDA

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